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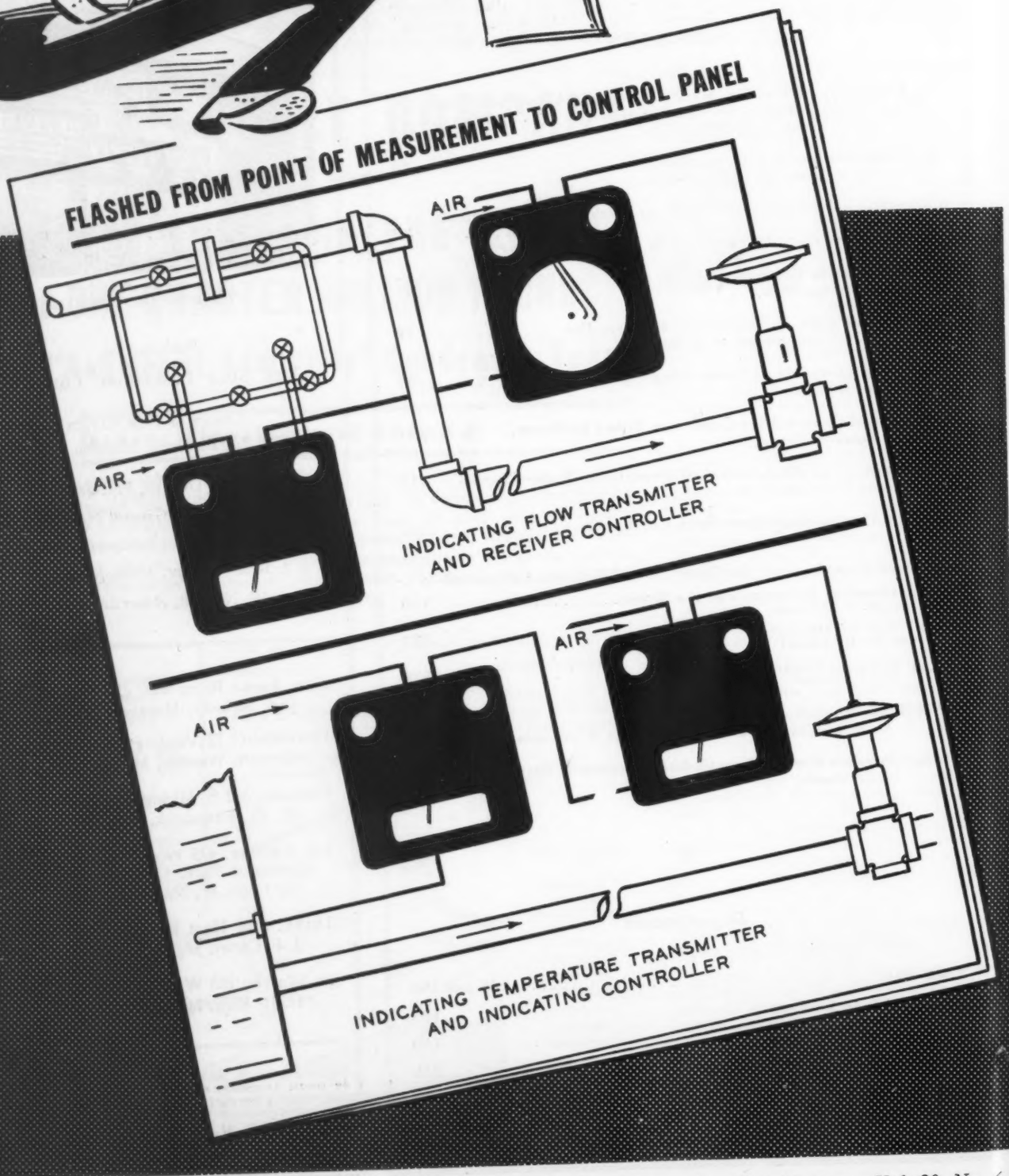

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REFINER
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A GULF PUBLISHING COMPANY PUBLICATION

The Look Box

INDUSTRY is subservient to the welfare of the nation. It has a role to play but its action must not get out of harmony with the objective of the nation. This applies especially in a crisis and crisis is one of several words now being used to describe what faces the United States.

Industry Must Serve By Doing Its Job

Oil is simply one phase of industry and its duty is to determine what its role is, to speak its lines distinctly and with proper emphasis on words, and to speak according to cue. Industry must play its part through the decisions and actions of men, so the duty of the oil industry is the duty of its personnel. It has raw materials in abundance. Its plant capacity is adequate, with only transportation in need of expansion and shifting. What men do with these physical things will determine how well the industry serves the welfare of the nation.

It would be excellent if men in business as well as politics were of one mind as to what action will be for the welfare of the nation. This is not true and there is confusion. This confusion will be lessened if men are determined to keep the welfare of the nation foremost.

Since the President spoke to the world May 27 there can be little doubt that the affairs of the United States are entrusted to the decisions of one man to a greater extent than ever before. Whether this is wise or unwise is a minor question and for the future. Laws have been passed by which the status of unlimited emergency came about. The status must be accepted.

Although no state of war exists it is common opinion that actual combat on the part of the United States is certain to come. This prospect has come about in large part by the conduct of other nations. Our own contribution to it may have been wise or unwise but settling that question must be left to historians.

There is common agreement that the United States needs a war machine more powerful than our military experts now vision. Its existence must be a reality within a short time. It must be manned by men who know its purposes and its limitations.

If the men of the industry and the men of government can concentrate on the creation of this machine their common objective will clear away some confusion. If the men of government and the men of industry can forget that industry is divided into capital and labor there will be further clarification. A stillman has as much at stake and is as much a part of industry as any technologist or executive and his contribution to the welfare

COMPLETE AND AUTHORITATIVE

MEETINGS of the American Petroleum Institute are concentration spots for developments in refining technology. The mid-year meeting in Tulsa May 19 to 22 was a summing up of developments in fuel economy and corrosion. No other meeting of technical experts brings so much knowledge to the attention of the industry.

Since comparatively few of the men who deal with refinery operation have opportunity to attend these meetings, Refiner and Natural Gasoline Manufacturer considers it a duty and privilege to give the information distribution that is as wide as the industry.

Accordingly the technical section of this issue is restricted to the papers that were presented at the Mid-Year meeting of the Division of Refining of the American Petroleum Institute.

of a nation is of as much value as that of any other workman.

More of our confusion would fade away if we could blend such words as capital, management and labor into one word—industry. Only industry can provide the war machine that will protect the welfare of the nation.

Plant Capacity Is One Third New

ALONG with the assurance of an adequate refining capacity the petroleum industry of the United States is fortunate in that a third of it is not yet four years old. This was one fact brought out in the census of refining and studies by the United States Bureau of Mines.

In commenting on this situation a recent release by the American Petroleum Institute gave this summary:

"Since the beginning of 1937 United States refiners have built new refining capacity of 1,383,982 barrels per day. This is equal to 33 percent of the present total operating capacity of the industry and to 30 percent of the total operating and shutdown capacity. In the same four years refiners have dismantled 959,894 barrels daily, leaving a net increase of 424,088 barrels."

Fitting the Man To the Job

WHILE industry is straining to get the full benefit of equipment it is significant that attention is being given to fitting men to jobs. A man in an improper activity is as uneconomic as a machine that is working contrary to its proper task.

The necessity of fitting men to their tasks was discussed before the Junior Board of Commerce in Philadelphia by Samuel L. H. Burk, chief job analyst of The Atlantic Refining Company as follows:

"The present defense emergency requires continuing and sound employer-employe relationships. Equitable wages and salaries are at the base of such relationships. Equity demands correct differentials among job rates within the company, based on differences in complexity and responsibility, as well as an adequate general level of wage rates, based on the going or market rates in the area for similar types of work. Furthermore, the most effective use of man-power cannot be achieved unless men are placed in jobs best suited to their training, education, aptitudes, abilities, and character traits.

"The scientific approach and systematic application of judgment are necessary to successful completion of present and future programs. The old rule-of-thumb methods will no longer serve to meet our complicated industrial needs.

"These ends cannot be achieved without detailed knowledge of job content and requirements. Job analysis is the management tool used for determining these facts and opinions. Job evaluation places jobs in the order of their relative difficulty and importance, and prices the resulting comparison schedule by means of the labor market survey. Modern selection and training methods make use of the information provided by job analysis in choosing individuals and aiding them in their adjustment to the job."

Octane Rating Is Difficult to Deliver

STATUS of the octane rating gasoline is an example of what technology can accomplish for an industry, which in turn can not assure delivery of the improvement to the consumer. In octane number gasoline has improved and continues to improve.

But the industry can not sell 83-octane gasoline with any assurance that it will be that sort of gasoline in an engine. Motors differ in how they burn gasoline. Frequently identical models fail to get identical results from one motor fuel. The many adjustments or maladjustments in spark settings and carburetion further complicate the task of delivering anti-knock rating to the customer.

No wonder technologists are baffled. The laboratory motor gives motor fuel a rating. Then a million automotive motors give the same gasoline a range in rating. The quality exists but the user fails to get its full advantage.

Often the sales department is prodding the technical department of an oil company. It might simplify the approach if the technical departments had a hand in shaping sales ambitions.

Delay Would Be Wise Even in Washington

BUSINESS as usual is as much out of place in government as it is in industry. Officials are justified in their complaint that too many men look upon national defense as an opportunity for maintaining business as usual.

So far as oil is concerned, it will profit nothing for the federal government to proceed with its anti-trust litigation against a score of oil companies and one of its associations. While the industry is struggling with such problems as a new transportation system between the Gulf Coast and the Atlantic Seaboard men will have little time to go before Congressional committees to testify as to the advisability of segregating pipe lines from other branches of the industry.

Right now the nation, not the industry, needs more pipe lines regardless of how they are owned.

The Economics of *Flue-Gas Recirculation* and Economizers in Fired Tubular Heaters for Oil Refineries

C. C. NELSON
Standard Oil Development Company

A SERIES of test runs made in 1926 upon a cracking-coil furnace, which had been equipped with a flue-gas recirculation system, indicated that this type of equipment is uneconomical for ordinary petroleum refinery heaters. As a corrective procedure for reducing excessive radiant-heat inputs in an existing setting, this operation appeared to be more economical than the use of high percentages of excess air, but even in these cases it is preferable to revise the furnace design rather than use recirculation.

Between 1926 and 1930, a number of air preheaters were installed on cracking coils and pipe stills in several domestic refineries. An economic study based upon a series of test runs on three of these cracking-coil installations indicated that a maximum gross annual return of 40 percent, excluding depreciation and maintenance charges, could be obtained, based upon 1926 prices. Based upon present construction costs and fuel prices, the estimated gross annual return on an equivalent installation would be reduced to 23.5 percent for a refinery located in the New York area, or to 15.5 percent for one located in the southern United States where lower fuel prices prevail. Even the 40-percent return was found to be inadequate to pay the excessively high maintenance and repair costs encountered, which were due mainly to fouling and corrosion. This, in turn, probably was caused by the poor-quality fuels usually burned at these units, and which must be utilized in normal refinery operation.

This paper was presented to Division of Refining, before the Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

FLUE-GAS recirculation and air-preheater systems were used fairly extensively in the petroleum industry a few years ago. At the present time, however, there appears to be a general trend away from the use of these types of equipment. In this paper it is proposed to examine the economic factors underlying this trend. Performance tests which were run on a number of plant installations from 10 to 15 years ago have been restudied on the basis of present-day costs and refinery practice to determine to what extent the conclusions reached at that time must be modified when modern installations are considered.

Flue-Gas Recirculation

The use of flue-gas recirculation in petroleum heaters is the subject of several patents by Bell.[1] It is carried out in furnaces of various common designs. All involve some means of returning a portion of the flue gas from the outlet of the furnace to some intermediate point, usually to a point just beyond the combustion zone. The primary purpose of this is to reduce the temperature in the radiant section of the furnace, thereby moderating the radiant-heat intensity. As a result of the increased quantity of flue gas, it is possible to obtain higher heat-transfer coefficients in the convection section of a given furnace; and, in addition, more uniform heat densities may be obtained throughout the entire convection section. Some designs for furnaces employing flue-gas recirculation go so far as to eliminate completely the radiant-section tubes and accomplish all of the oil heating in convection tubes.

The experience of Standard Oil Company of New Jersey with flue-gas recirculation dates from about 15 years ago. With the types of heaters then in use, without flue-gas recirculation, considerable difficulty was experienced due to excessive high radiant-heat inputs, resulting in high tube-metal temperatures and the danger of tube failures. It was common practice to alleviate this condition by firing with high percentages of excess air, which resulted in low heat efficiencies. Under these conditions, the adoption of flue-gas recirculation as a substitute for operation with high percentages of excess air indicated a very considerable fuel saving. Accordingly, a test installation was made on a cracking coil in one of the refineries.

Several test runs were carried out with an existing cracking furnace (shown in Figure 1) which had been equipped with both a flue-gas recirculation system and an air preheater. The equipment was arranged so that the two systems could be used separately or in combination. A summary of the results obtained is given in Table 1.

The installation cost of the flue-gas and air-preheat equipment on this unit was considerably higher than originally expected. This was due in part to the use of an existing furnace which had not been designed originally for this type of equipment and, also, due to the requirement of having the preheater circuit entirely separate from the flue-gas recirculation circuit so that both could be operated either singly or simultaneously.

The fuel savings have been evaluated on three different bases: *a,* using a fuel-oil price of $1.68 per barrel, which was used in the original economic study in 1926; *b,* using $1.20 per barrel as a typical current New York area price; *c,* using $0.80 per barrel as a typical current price in the southern part of the

United States. It is apparent that the gross annual return on this equipment is much lower at present fuel prices than it was in 1926, assuming the same installation cost. Even at the high fuel value, however, it is unlikely that the indicated 43 percent gross annual return is sufficient to meet depreciation, maintenance, and power costs. The general subject of maintenance and repairs will be considered later in connection with air preheaters. No figures are available on the actual maintenance cost of this flue-gas recirculating equipment, because the furnace setting was rebuilt in the following year and the recirculation system was not reinstalled.

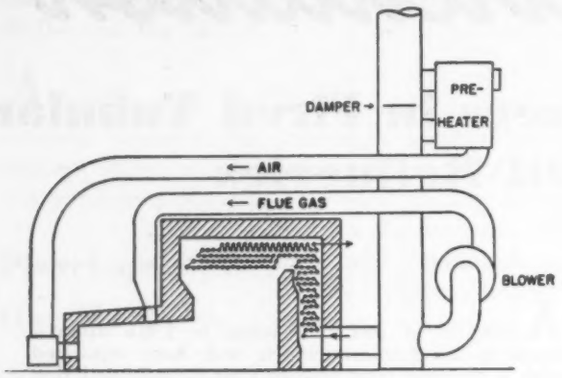


FIGURE 1
Furnace Employing Both Air-Preheater and Flue-Gas Recirculation System.

Considerable difficulty was encountered in the operation of the furnace when an attempt was made to fire oil fuel, due to the fact that combustion was not complete at the point of introduction of the recirculated flue gas. It was necessary finally to go to gas firing in order to get good combustion conditions. This, however, is a matter of furnace design and burner selection, and has no direct bearing on the merits of flue-gas recirculation as such.

Flue-Gas Recirculation Vs. Furnace Design

The general conclusion which was reached from the foregoing experience was that the use of flue-gas recirculation as a means of moderating heat inputs was not economically desirable. Subsequent experience has shown that substantially the same results can be obtained by modifying the furnace design so that excessive radiant-heat inputs are not encountered even at low percentages of excess air. Furthermore, the improvement in burner design in recent years has made possible also the construction of furnaces with fairly uniform radiant-section heat distribution.

Once satisfactory furnaces are developed which operate with low percentages of excess air, there is little further advantage in the use of flue-gas recirculation. As pointed out by W. L. Nelson,[2] it is theoretically possible to decrease the required tube surface slightly by the use of flue-gas recirculation, but it is concluded that the decrease is not sufficient to pay for the installation of this equipment. The convection-section heat density can be made much more uniform, but the average remains about the same; and, so long as overheating does not occur in the region of maximum heat input, no particular gain is effected. It is realized, of course, that special cases may arise, when stocks are being handled at unusually high temperatures, when there might be merit in some sort of a recirculation system. For the general type of heaters now in common use in the petroleum refineries, however, it is concluded that flue-gas recirculation is economically undesirable.

Air Preheaters

Air preheaters are used widely on steam boilers and various other types of industrial furnaces. They still are used by a number of petroleum refining companies, although their use has been discontinued by the refineries associated with Standard Oil Company (New Jersey). This discussion is limited to the economic aspects of the use of air preheaters, and does not consider the details of design and construction of this equipment, because these are fairly well standardized and adequately described in the literature.

The effect of air preheat upon the operation of the furnace is just the opposite from that of flue-gas recirculation, in that the use of preheated air increases the temperature of the combustion zone and causes a higher ratio of radiant- to convection-section heat. This may necessitate increasing and rearranging the radiant-section surface, with a corresponding reduction in convection surface, in order to avoid overheating of the radiant-section tubes.

The economic desirability of air preheaters is determined in the usual manner for any particular case by balancing the value of the fuel saving against the depreciation, maintenance, and power cost of the installation. In addition, it is necessary to consider

TABLE 1
Flue-Gas Recirculation Tests

Operation	Normal		With Flue-Gas Recirculation		Flue-Gas Recirculation and Air Preheat	
Run	1	2	3	4	5	6
Total flue gas at furnace outlet, pounds per hour	22,100	19,400	24,100	24,000	26,800	26,900
Recirculated flue gas, pounds her hour	0	0	10,000	10,000	12,000	12,000
Excess air at furnace outlet, percent	83	71.5	20	23	12	13
Flue-gas temperature leaving furnace, °F	833	658	794	777	918	769
Flue-gas temperature in stack, °F	.....	.....	749	715	281	319
Fuel oil required for 10,000,000 Btu heat pickup, gallons per hour	113		99.5		86	
Fuel saving, gallons per hour	.....		13.5		27	
Installation cost,* dollars	.....		9,000		20,000	
Value of fuel saved, dollars per year:						
a. At $1.68 per barrel, New York, 1926	.....		3,900		7,800	
b. At $1.20 per barrel, New York, 1941	.....		2,800		5,600	
c. At $0.80 per barrel, southern U. S., 1941	.....		1,850		3,700	
Annual return (excluding depreciation, maintenance, and power cost),† per cent:						
a. Based on fuel costs given above	.....		43		39	
b. Based on fuel costs given above	.....		31		28	
c. Based on fuel costs given above	.....		20.5		18.5	

* This was actual cost of complete installation at existing furnace. This was considerably higher than estimated originally.
† Power consumption was not measured on these tests. Preheater fan had a 10-hp motor drive. Recirculating fan was driven by a 30-hp steam engine.

TABLE 2
Air-Preheater Tests—Cracking-Coil Furnaces

	Series 1		Series 2		Series 3	
	Without Pre-heater*	With Pre-heater*	Without Pre-heater†	With Pre-heater†	Without Pre-heater‡	With Pre-heater‡
Pounds of flue gas per hour	21,000	20,500	20,400	16,300	34,400	41,000
Stack temperature, °F.	660	360	640	305	1,040	495
Excess air, percent	70	90	33	23	70	130
Fuel fired, gallons per hour	105	92	127	109	153	137
Fuel saved by preheater, gallons per hour	.....	13	.....	18	.....	16
Electric power used by preheater fan, kilowatts	.....	7	.....	6	.....	29
Power cost, dollars per year:						
a. At $0.01 per kilowatt-hour, 1926	500		430		2,100	
b. At $0.004 per kilowatt-hour, 1941	200		175		833	
Original cost of preheater installation, dollars	11,000		12,000		10,750	
Estimated cost of equivalent modern installation, dollars	15,000		15,000		16,300	
Value of fuel saved, dollars per year:						
a. At $1.68 per barrel, New York, 1926	3,750		5,200		4,600	
b. At $1.20 per barrel, New York, 1941	2,700		3,700		3,300	
c. At $0.80 per barrel, southern U. S., 1941	1,780		2,500		2,200	
Annual return (excluding depreciation and maintenance), per cent:						
a. Original installation, 1926 costs	29.5		40		23	
b. Modern installation, New York area	16.7		23.5		15.1	
c. Modern installation, southern U. S.	10.5		15.5		8.4	

* Average of 6 test runs. † Average of 3 test runs. ‡ Average of 2 test runs.

other alternative means of utilizing the same waste heat as a possible preferable solution to the problem.

It is the usual practice to design petroleum refinery heaters for an exit flue-gas temperature which approaches the cold-oil inlet temperature by a predetermined number of degrees. This optimum temperature approach is computed for any given case by making an economic balance between the incremental cost of convection-section heating surface and the value of the additional heat recovered. For any particular design, therefore, increasing the cold-feed-stock inlet temperature raises the exit flue-gas temperature with a corresponding increase in the heat lost to the stack. At these higher flue-gas temperatures, reboilers, steam generators, and air preheaters come into consideration as possible methods of recovering some of this waste heat.

Considerably more experience has been had with air preheaters than with flue-gas recirculation systems. Preheaters have been used on a number of pipe stills, as well as cracking coils. An extensive series of preheater tests is summarized in Table 2. These tests were run between 1926 and 1930. In all cases, several tests were made both with and without using the air preheaters under as nearly comparable conditions of feed rate, operating temperatures, and pressures, etc., as it was possible to obtain experimentally. The fuel savings tabulated are those actually measured during the test runs. The fuel savings have been evaluated for the same three different fuel prices which were used for the flue-gas recirculation data of Table 1. In addition to the actual costs of the original air-preheater installations, figures are tabulated giving the estimated costs of modern air-preheater installations for equivalent service. The figures presented for the gross annual return at present fuel prices have been based upon these estimated present-day installation costs.

The tests tabulated under series 1 in Table 2 were run on the same furnace that was used for the flue-gas recirculation tests (shown in Figure 1). Series 2 tests were run on this setting a year later, after the furnace had been rebuilt. The Dutch oven was removed and the radiant section enlarged to permit the installation of an increased number of radiant tubes. The tests of series 3 were run on a unit in a different refinery, which was very similar in furnace design to that of series 1. This difference in furnace construction shows up in the operation of the furnaces in the percentage of excess air required. In series 1 and 3, the percentage of excess air are high in order to prevent the overheating of the small number of radiant tubes. It is to be noted also that in these two cases it was necessary to use more excess air when the air preheater was used, which is in agreement with the general statement that air preheat increases the radiant-section heat intensity.

In series 2, however, apparently overheating of the radiant tubes was not encountered, and the amount of excess air probably was limited by the combustion requirements. In this case, the use of preheated air actually reduced the excess air required for satisfactory operation. This test probably represents fairly closely the performance which reasonably might be expected from a modern unit today.

It is noted that, at the present price level, the use of air preheaters is much less attractive economically than at the time these installations were made originally. Even at the high fuel price, experience indicated that the 40 per cent gross annual return was insufficient to carry the high depreciation and maintenance costs on this equipment. It, therefore, was concluded that the use of air preheaters was economically undesirable for petroleum heaters of this type, and their use has been discontinued in these refineries.

In addition to these cracking-coil installations, air preheaters have been used on a number of pipe stills. No extensive comparative tests are available, but, in general, the costs and performance were very similar to those obtained on the cracking units. In this case, also, the use of preheaters was discontinued because of excessive cleaning and maintenance charges.

Maintenance and Repairs

Probably the most important, and at the same time the most difficult to evaluate, of the factors which determine the economic desirability of flue-gas recirculation and air-preheating equipment is that of maintenance. Unfortunately, the detailed

[*Continued on page 129*]

Air Preheaters

For Petroleum Heaters

L. A. MEKLER and H. A. BECKER
Universal Oil Products Company

THE petroleum industry consumes the equivalent of approximately 100,000,000 barrels of fuel per year. Because of ease of handling and response to manual and automatic control, refinery and natural gas represent 65 percent of the total. Improvement in refinery technique reduced the production of non-salable solid and liquid by-products, and processing of refinery gas to the ultimate may diminish greatly the supply of the gaseous fuels. Fuel savings, therefore, are an economic and operating necessity. Installation of air preheaters may save up to 25 percent of the fuel used by refinery heaters.

The use of air preheat on a heater designed for cold air does not affect heat distribution materially if the heater is operated at the original capacity. With a given amount of fuel burned, an increase in capacity can be obtained with air preheat if the higher radiant-heat-transfer rates obtained with higher heat liberation and higher flame temperatures due to air preheat are permissible in the heater.

Recuperative preheaters are the most commonly used for a wide range of flue-gas and air preheat temperatures. Regenerative preheaters may be more suitable for the highest ranges. The cost of recovering a given portion of heat by air preheat varies inversely with the size of the heater, and passes through an optimum for each heater as the portion of heat recovered is increased. Operation of preheaters far beyond the optimum point may result in air preheating becoming unprofitable.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

THE petroleum industry is one of the largest industrial consumers of fuel, using the equivalent of approximately 100,000,000 barrels of fuel oil per year, which represents between 8 and 12 percent of the heat content of the crude oil processed. The fuel requirements of the different refining operations may vary from 2 percent of the crude processed for simple distillation up to 20 percent for some of the thermal and catalytic processes.

Until quite recently most refineries produced non-salable by-products in quantities greater than their fuel requirements, so that there was little, if any, incentive to conserve fuel by improving the firing practice and by the installation of fuel-saving equipment. Improvements in oil-refining technique practically have eliminated the non-salable liquid, semi-liquid, or solid by-products, and the development of new processes materially is reducing the quantities of gaseous by-products that are available for fuel. Most refineries, therefore, are using marketable fuels to a greater or lesser extent, so that fuel becomes an out-

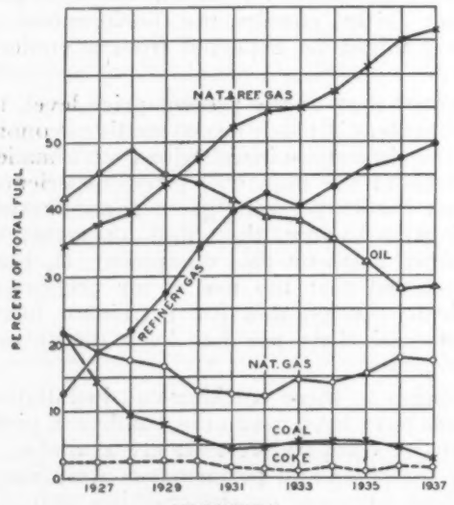


FIGURE 1
Relative Importance of Fuels Used in Refineries.

of-pocket expense that may affect the net earnings of refinery operations.

Figure 1 shows the relative importance of the different fuels used in refineries in recent years, as disclosed by a survey of the Bureau of Mines. The trend is definitely away from solid and liquid fuels in favor of gaseous fuels, because these latter fuels are more amenable to manual—and particularly to automatic—control, which is desirable in the more exact refining operations carried out at present. In 1937 refinery and natural gas represented better than 65 percent of the total fuel consumption of the refineries covered by the survey—with fuel oil, coal, and coke together making up the remainder. Although the present trend is toward a still greater use of gaseous fuel, the available supply of gaseous fuel, particularly of refinery gas, is on the decline because of the utilization of refinery gas as raw material for the various processes for the manufacture of high anti-knock motor fuels, alcohols, intermediate chemicals, etc.

Depletion of Heating Value

Table 2 and Figure 2 show the rate of depletion of the available heating value of a representative cracking-plant gas shown in Table 1 after this gas has been subjected to certain processes for ultimate yield of high anti-knock motor fuels. Depend-

TABLE 1

Composition and Heating Value of Typical Dubbs Cracking-Plant Gas

Component	Mol. Percent	Heating Value (Btu per Cubic Foot)		ΣHeating Value (Btu per Cubic Foot)	
		Gross	Net	Gross	Net
H_2	6.4	325	274	21	18
CH_4	30.6	998	900	305	276
C_2H_4	5.1	1,591	1,491	81	76
C_2H_6	19.1	1,759	1,610	336	308
C_3H_6	10.6	2,347	2,198	249	233
C_3H_8	16.8	2,532	2,330	425	392
C_4H_8	5.9	3,148	2,933	186	173
C_4H_{10}	5.5	3,329	3,076	183	169
Total	100.0	....	....	1,786	1,645

Specific gravity—1.05.

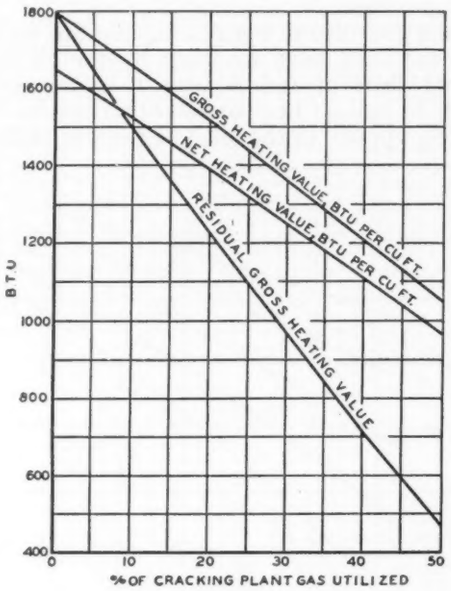


FIGURE 2
Rate of Depletion of Heating Value of Cracking-Still Gas with Processing.

ing on the processing methods used, the gross heat available per cubic foot of the original gas is reduced from 1786 Btu per cubic foot to 744 Btu per cubic foot in one case, and to 1169 Btu per cubic foot in the other—representing a loss of 58½ percent and 34½ percent, respectively. Fuel economies in refineries, therefore, become desirable not only because of possible direct savings in the refining costs, but also

TABLE 2

Depletion of Heating Value of Cracking-Plant Gas By Various Processing Methods

Processing Method	Cubic Feet	Heating Value (Btu per Cubic Foot)		Residual Gross Heat Available Per Original Cubic Foot
		Gross	Net	
Original gas	1.000	1,786	1,645	1,786
After selective polymerization	0.971	1,748	1,605	1,698
After selective and non-selective polymerization	0.835	1,620	1,482	1,352
After selective and non-selective polymerization and butane dehydrogenation	0.780	1,498	1,372	1,168
After selective and non-selective polymerization and butane and propane dehydrogenation	0.612	1,215	1,110	744
Alternate Processing Method				
After alkylation	0.923	1,678	1,532	1,550
After alkylation and dehydrogenation	0.886	1,600	1,471	1,418
After alkylation, dehydrogenation, and non-selective polymerization	0.780	1,498	1,392	1,169

because they permit conservation of the diminishing supply of gaseous fuel, the use of which is often a necessity in some of the thermal and catalytic oil-refining processes.

Most oil-refining operations are carried out at comparatively high incoming-oil temperatures because of heat exchange between the incoming oil and hot liquids or vapors produced in the refining operation. Conservation of cooling water or a desire to obtain certain specific types of fractionation often is the main cause of such heat exchange—the fuel savings being of secondary consideration. Because of the high inlet-oil temperatures, the temperature of the gases leaving most petroleum heaters is also comparatively high, ranging between 700 and 1400° F. Depending on the amount of excess air used for combustion and the stack temperature, the losses in the flue gases may be as high as 40 percent of the generated heat, and are seldom less than 25 percent. These losses may be cut to less than half by heat-exchanging the flue gases with the air used for combustion.

Economy of Heat-Exchanging Flue Gas

Figure 3 shows the savings of fuel that can be obtained by heat-exchanging flue gases at temperatures of 800, 1000, 1200, and 1400° F., with the air

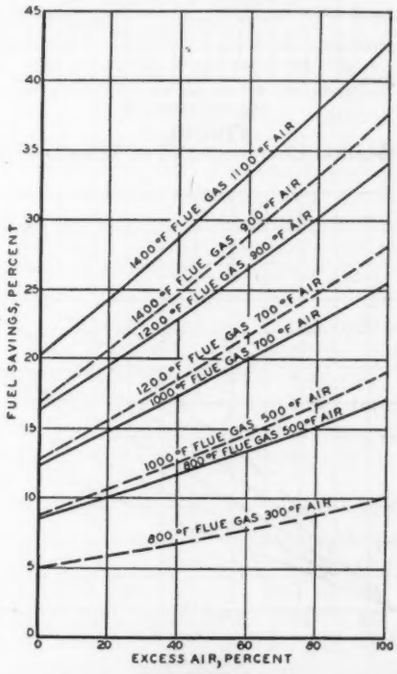


FIGURE 3
Fuel Savings Due to Air Preheat

used for combustion to preheat the air to within 300 and 500° F. of the respective flue-gas temperatures when an average mixture of natural and refinery gas with various percentages of excess air is burned. The combustion characteristics of the gas are shown in Figure 4. The fuel requirement at given flue-gas temperature and excess air, with no air preheat, is used as a base in the curves of Figure 3. For example, with a flue-gas temperature of 800° F. and 50 percent excess air preheating the air to within 300° F. of this temperature (500° F. air) saves 12.5 percent of the fuel that would be required with the same excess air if no air preheat were used.

Figure 5 shows more specifically the savings that

can be obtained by recovering heat from flue gases at an original temperature of 1070° F. by preheating the air to temperatures up to 700° F., with various percentages of excess air used for combustion. The fuel requirement for any given excess air and with no air preheat is used as a base in these curves. The

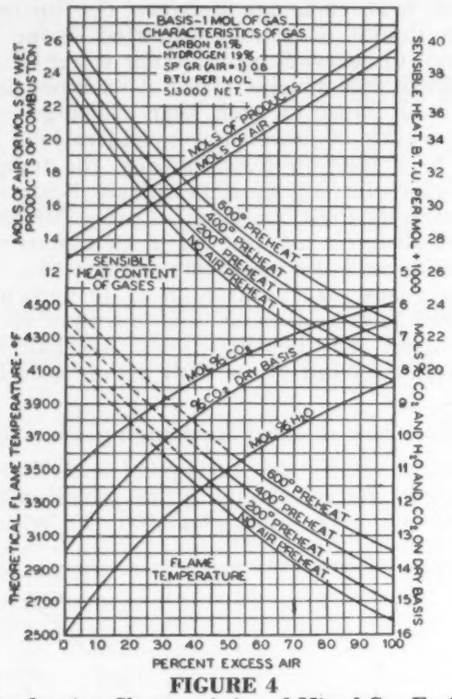


FIGURE 4
Combustion Characteristics of Mixed-Gas Fuel.

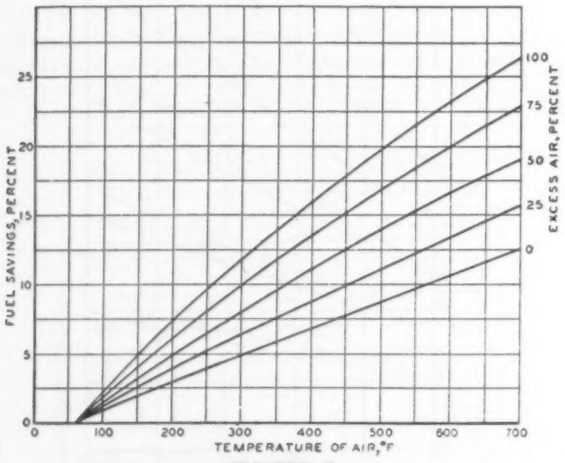


FIGURE 5
Fuel Savings with Air Preheat for Various Air Temperatures and Excess Air Used—Flue-Gas Temperature, 1070° F.

curves show that the higher the excess air that must be used in a given heater, the greater are the savings obtainable with air preheat.

Economy of Air Preheat

Figure 6 shows the fuel saving that can be obtained by air preheat, by reduction of the excess air used, and by a combination of both. The fuel requirement with 100 percent excess air and no preheat is used as a base in these curves. The curves show that within certain limits of possible savings, air preheat and reduction of excess air are interchangeable, and that the savings obtained by using both are cumulative. For example, a reduction of excess air from 100 percent down to 50 percent without air preheat results in a fuel saving of approximately 13 percent, which is equivalent to the saving that can be obtained by preheating the air to 340° F. without reducing the excess air used. By reducing the excess air to 50 percent and preheating the air to 340° F., a cumulative saving of approximately 21 percent of the fuel used with 100 percent excess air and no air preheat can be obtained.

With other things being equal, preheating of air results in more rapid and complete combustion so that, for given flame characteristics, the use of preheated air will assist in reducing the excess air used for combustion—thus making the cumulative fuel savings possible.

Modern petroleum heaters supply the major portion of the total heat absorbed by the oil by radiation, and their operation usually is determined by the rates of radiant-heat transfer that can be obtained and safely applied to the oil. The rates of radiant-heat

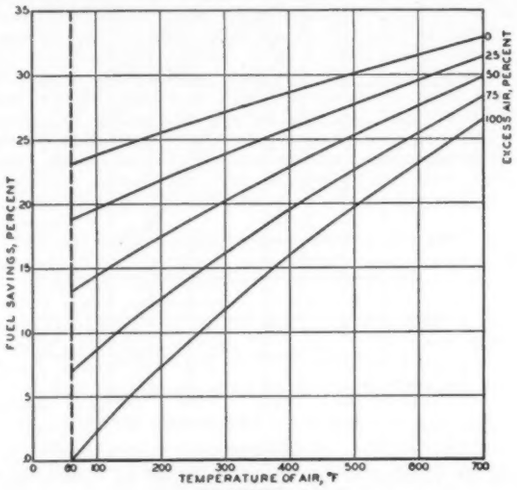


FIGURE 6
The Effect of Air Preheat and Excess Air on Fuel Savings—Flue-Gas Temperature, 1070° F.

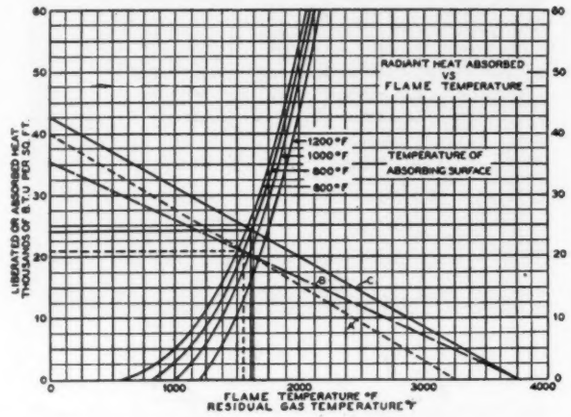
transfer are determined by the flame temperature and by the quantity of heat liberated per square foot of projected effective heat-absorbing surface subjected to radiation. The relationship between the flame temperature, the quantity of liberated heat, radiant-heat absorption, and residual-gas temperature is shown in Figure 7.

Air preheat increases the flame temperature. Air preheat, however, results in a reduction in the amount of fuel used, so that, even with the additional heat brought in by the preheated air, the heat liberation per square foot of effective projected surface for a given capacity of the heater is lower with air preheat than without it. The increase of radiant-heat absorption due to higher flame temperature is almost equal to the decrease due to lower heat liberation. Therefore, if the heater is operated at the same capacity in each case, the total radiant-heat absorption in a heater and the relationship between the radiant and convection heat pickup remain practically the same whether preheated air or cold air is used. Preheated air can be used to increase the total capacity of a heater designed for cold-air firing, provided the increase will not overload the radiant-heat-absorbing surfaces which will be affected most by this increase. Higher amounts of liberated heat obtained at the higher capacity and the higher flame

temperature obtained with preheated air will have an accumulative effect, so that the radiant-heat transfer rates will increase almost in proportion to the increase in capacity. The convection rates are changed very little with air preheat, within the range of capacity increase that is safe for the radiant-heat-absorbing surfaces.

Recuperative Preheaters

Air preheaters can be divided into two main classes—recuperative air preheaters and regenerative air preheaters. In recuperative preheaters the heat interchange between the flue gases and the air is obtained by continuous heat flow from the flue-



Examples	A	B	C
	No Air Preheat	Preheated-Air Temperature, 660° F. Heater Capacity Same as "A"	Preheated-Air Temperature, 660° F. Heater Capacity Increased 15 Percent
Flame temperature, °F	3,250	3,750	3,750
Liberated heat per square foot of equivalent effective surface, Btu	40,000	36,000	42,500
Temperature of heat-absorbing surface, °F	800	800	800
Absorbed radiant heat per square foot of equivalent effective surface, Btu	21,000	21,000	24,000
Residual temperature of gases, °F	1,550	1,550	1,580

FIGURE 7
Radiant-Heat-Absorption Relationships.

gas stream to the air stream through a membrane which separates the streams from each other. With normal flue-gas and air-flow conditions, this membrane is maintained at a substantially constant equilibrium temperature at any given point. The equilibrium temperature is approximately the mean of the flue-gas and air temperatures at the point of contact. In properly designed recuperative air preheaters all elements perform in a similar manner, and the flue-gas and air streams leave the preheater at substantially constant temperatures.

Regenerative Preheaters

In regenerative preheaters the heat interchange is obtained by storing heat from the flue gases in the elements while they are in the flue-gas stream during the heating cycle, and by the recovery of this heat by the air while the elements are in the air stream during the cooling cycle. The elements of regenerative air preheaters vary in temperature from substantially the temperature of the flue gases at the highest point to substantially the temperature of the air at the lowest point of the temperature cycle. Regenerative preheaters may be of the stationary-element type, containing two sets of elements—one set being heated while the other is being cooled, with the flow of air and flue gas alternately reversed from one set to the other; or they may be of the rotating-element type—wherein the elements are made to pass, for one portion of the cycle, through the gas stream to absorb the heat from it and, for the remainder of the cycle, through the air stream to transfer the stored heat to the air.

In regenerative air preheaters with stationary elements, the temperatures of the cooled flue gases and the preheated air leaving the preheater vary through each cycle. The shorter the cycles, the more uniform these temperatures will be. In regenerative preheaters with rotating elements, while the individual elements go through a cyclic temperature change, the banks of elements in the flue-gas stream and the air stream are maintained at constant mean temperatures by continuous substitution of hot and cold elements in each bank. Therefore, the temperature of the flue gas and air leaving preheaters with rotating elements is substantially constant.

Air preheaters used on petroleum heaters employ metallic heat-exchange elements. Carbon steel, plain or copper-bearing, is the metal most commonly used. When high gas-inlet temperatures and high degrees of air preheat are used so that the heat-exchange elements are subjected to metal temperature in excess of 900° F., or when sulfur-containing fuels producing corrosive products of combustion are burned, oxidation- and corrosion-resistant steels such as 4- to 6-percent chrome, 12-percent chrome, and 18-8, may have to be used locally or throughout the entire preheater. In recuperative air preheaters the highest obtainable metal temperature is approximately the mean of the highest flue-gas temperature and the highest preheated-air temperature. In regenerative air preheaters, the highest metal temperature approaches the highest flue-gas temperature. For given flue-gas and air-preheat temperature, the maximum metal temperature in a recuperative air preheater is considerably lower than it is in a regenerative type.

The effectiveness of heat-exchange elements in both the regenerative and recuperative air preheaters is determined by the logarithmic mean-temperature difference between the flue gas and the air and the overall heat-transfer coefficient which, in turn, is determined by the velocity of the gas and the air streams. Preheaters with large temperature differences and high velocities will, therefore, be smaller and less expensive than preheaters with a close approach between the flue-gas and the air temperatures and low velocities. However, high temperature differences can be obtained only in preheaters that recover a small fraction of the heat available in the flue gases. High air and flue-gas velocities result in high draft losses through the preheater and, therefore, require more power for the propulsion of the air and the flue gases through the preheater. Therefore, for a given fuel saving a small preheater with effective heat-exchange elements—although requiring a lower capital investment—will have a higher operating cost than a larger air preheater with less effective elements. An economic balance between the value of the fuel saved, the fixed charges, and the operating cost usually deter-

mines which air preheater best is suited for the particular installation.

Plate and Tubular Air Preheaters

Recuperative air preheaters can be divided into plate air preheaters and tubular air preheaters, depending on the type of heat-exchange elements used. Figure 8 shows schematically a typical plate air preheater. The preheater consists of a number of air chambers or "envelopes" equidistantly spaced in a casing. The air passes through the envelopes, and the flue gases between them. To keep the draft losses on the gas side to a minimum, the flue gases pass straight through the preheater from the bottom to the top. The air is made to change the direction of its flow through the envelope to increase the washing effect of the air upon the surface, and to accommodate air-inlet and -outlet connections most suitable for the particular installation.

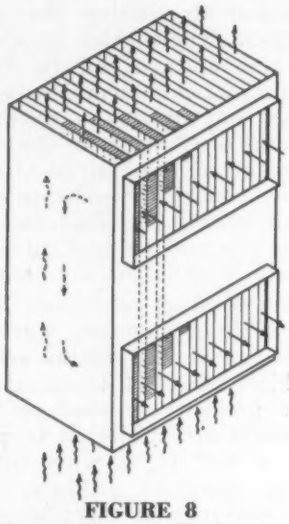


FIGURE 8
Typical Plate Air Preheater.

The various types of air flow that commonly are used in plate air preheaters are shown in Figure 9. **C** flow is obtained on the preheater in Figure 8, with the air-inlet and -outlet connections as shown. The **C, S,** and **L** flows in Figure 9 are shown with countercurrent flows of the air and the flue gas which give the most effective use of the heat-exchange surface employed and the closest approach between the temperature of preheated air and the temperature of the incoming gas. When only a relatively small percentage of the available heat in the flue gas is recovered in air preheaters, concurrent gas and air flows with the same types of air flow as shown in Figure 9 often are used to simplify the duct arrangement. For the same amount of air preheat a greater amount of heating surface is required with concurrent than with countercurrent flows. With the same amount of heating surface, higher air preheats can be obtained with countercurrent than with concurrent flows. The cross-flow is limited to air preheaters with short elements. The gas- and air-flow relationship in this flow is neither countercurrent nor concurrent. Under identical conditions of gas and air quantities, heating surface, and intitial gas temperature, the heat recovery with cross-flow is less than with countercurrent flow, and more than with concurrent flow for the **C, S,** and **L** air flows shown.

With the **C, S,** and **L** flows, the temperature of the air leaving the envelopes is uniform throughout the cross-section of each envelope. With cross-flow and the gas flow as shown in the diagram, the temperature of the air leaving the bottom portion of each envelope is considerably higher than that of the air leaving the top portion, and the temperature of the preheated air as delivered to the burners is somewhere between these two temperatures. A thorough mixing of the air on the outlet of the preheater is necessary with a cross-flow to avoid delivering air of a different temperature to the different burners.

Figures 10, 11 and 12 shows the different types of construction used for the envelopes of plate-type air preheaters. Figure 10 shows a phantom assembly of a welded-plate envelope air preheater, arranged for countercurrent flow of gas and air, and **C** flow of the air. The envelopes are made by welding two prefabricated plates all along their line of contact, with the exception of the air-inlet and -outlet openings. The construction of the envelope opening and the method of assembly are shown in phantom at the right-hand corner of the air inlet. The same construction is used at the air outlet.

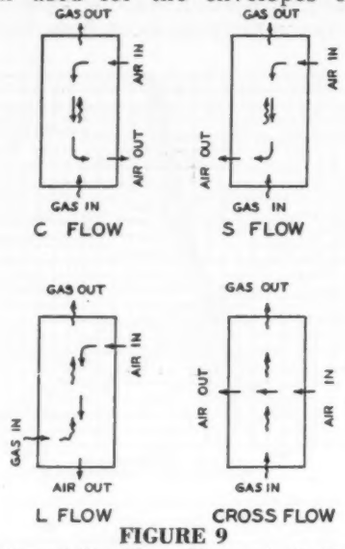
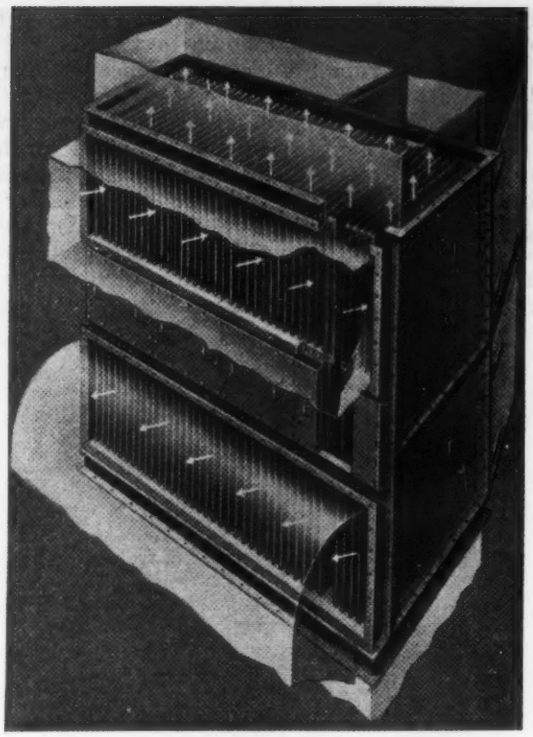


FIGURE 9
Typical Air and Gas Flows Through Air Preheaters.

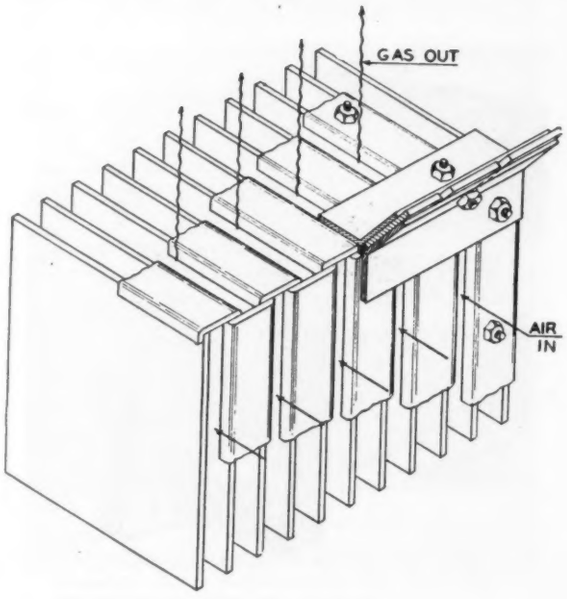
Figure 11 shows a schematic assembly of an air preheater with clamped-plate envelopes. The gas and air passages are formed by alternately clamping flat plates in special channels which form the side closures. Sufficient pressure is applied upon clamping rods, **C,** by the wedge head bolts, **D,** to make the joint sufficiently tight for the air and gas pressures normally prevailing in air preheaters. The joint, however, is loose enough to permit a slight movement of the plate between the tightening rod and the channel to take care of small amounts of differential expansion within the envelope—which is one of the advantages claimed for this construction. Figure 12 shows a photograph of a preheater of this type.

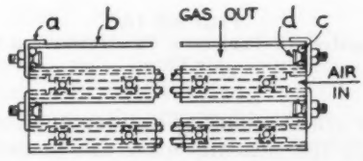
Figure 13 shows a schematic assembly of an air preheater with the envelopes made of welded corrugated or undulated plates. Alternate plates are undulated at right angles to each other to obtain the maximum turbulence of air and gas flow through the preheater, so that higher heat-transfer rates are obtained with a given size envelope than can be obtained with flat plates. The undulations are less frequent and are shallower across the gas flow than



Courtesy B. F. Sturtevant Company.

FIGURE 10
Phantom Assembly of Welded Flat-Plate Envelope Air Preheater.





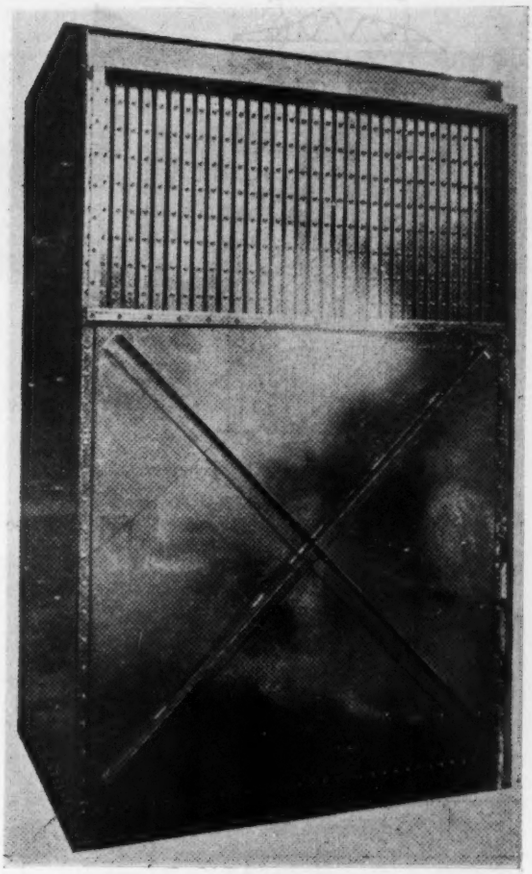
Courtesy Prat-Daniel Corporation.

A—Side Channel.
B—Flat Plate.
C—Clamping Rod.
D—Wedge Bolt.

FIGURE 11
Schematic Assembly of Flat Clamped-Plate Envelope Air Preheater.

they are across the air flow to keep the draft losses on the gas side to a minimum, and to minimize the tendency of the gas passages to foul. Preheaters with undulated-plate envelopes are limited to use with clean burning fuels.

Plate air preheaters are usually installed with a forced-draft (cold-air) fan to overcome the resistance



Courtesy Prat-Daniel Corporation.

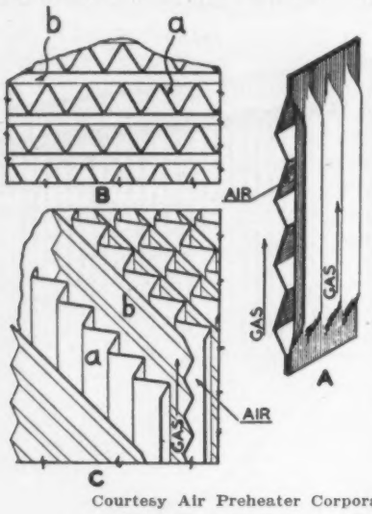
FIGURE 12
Clamped Flat-Plate Envelope Air Preheater.

to the air flow through the envelopes. Stack draft may be used to induce the gas flow through preheaters designed for comparatively low heat recoveries, when gas-outlet temperatures can be kept high to produce the draft and when wide gas spacings can be used to keep the draft loss through the preheater low. An induced-draft (exhaust) fan normally is used for a high-heat-recovery plate air preheater.

Figure 14 shows a tubular air preheater in which the heat-exchange elements consist of a number of tubes expanded into an inlet and outlet header. The gas passes through the tubes, and the air passes on the outside of the tubes. Tubular air preheaters usually are arranged for more than two passes of the air across the tube elements, and may have concurrent or countercurrent flow of air and gas. The air flow shown in Figure 14 is a combination of cross-flow and a countercurrent **S** flow developed especially for applications with high inlet-gas temperatures and comparatively high air-outlet temperatures to avoid the use of high-temperature-resistant alloys. Cold air entering the hottest gas section of the preheater keeps the mean temperature of the metal at

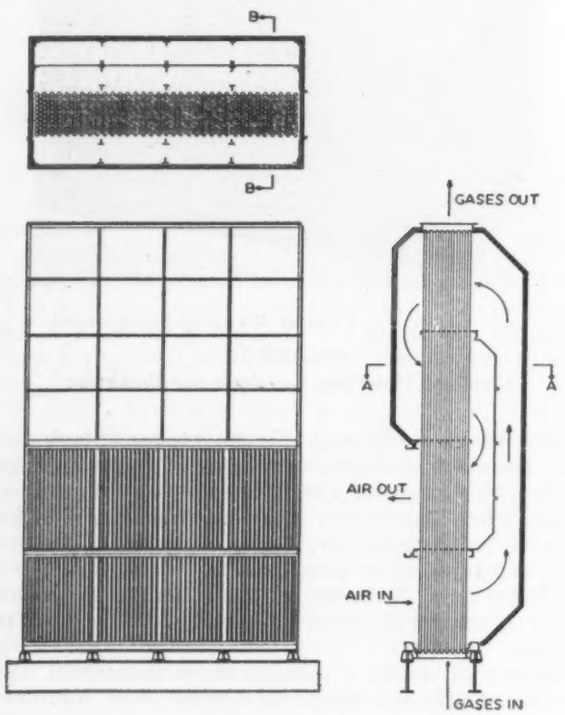
this point much below that which would be obtained if a strictly countercurrent flow were used.

For a given gas-inlet and air-outlet temperature this type of flow requires more heat-exchange surface, and results in higher draft losses than does the countercurrent flow. However, with strictly



Courtesy Air Preheater Corporation.

FIGURE 13
Schematic Assembly of Corrugated Welded-Plate Air Preheater.



SECTIONAL ELEVATION B-B

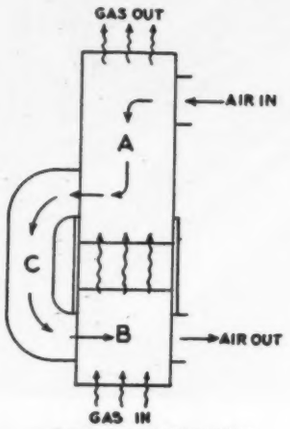
Courtesy Foster-Wheeler Corporation.

FIGURE 14
Tubular Air Preheater

countercurrent flow and the inlet-gas and outlet-air temperatures for which the preheater in Figure 14 is intended, a two-section air preheater as shown in Figure 15 would be required. The two-section preheater is used with both plate and tubular elements to obtain a closer approach between the temperature of the preheated air and the high-temperature flue gas than can be obtained with a flow through the preheater as shown in Figure 14.

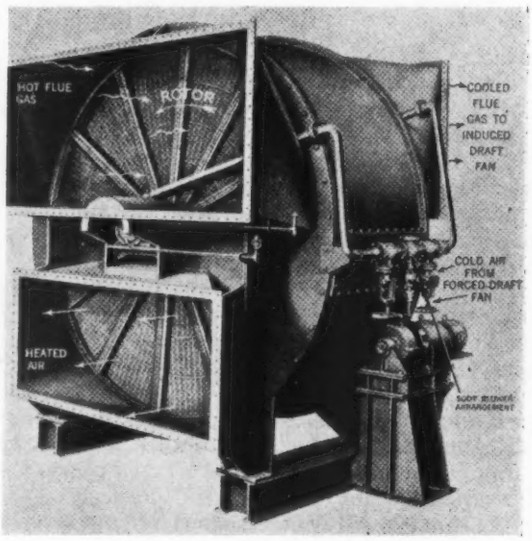
As a general rule tubular air preheaters are installed with forced- and induced-draft fans.

Figure 16 shows a regenerative air preheater with rotating heat-exchange elements arranged for horizontal flow of gas and air through the preheater. Figure 17 shows the same type of preheater arranged for vertical flow. The preheater consists of a rotor made up of segments of closely packed undulated plates, as shown in detail in Figure 18, revolving in a casing provided with gas- and air-inlet



A—carbon-steel section.
B—alloy section.
C—outside-air cross-over

FIGURE 15
Schematic Arrangement of Two-Section Air Preheater.



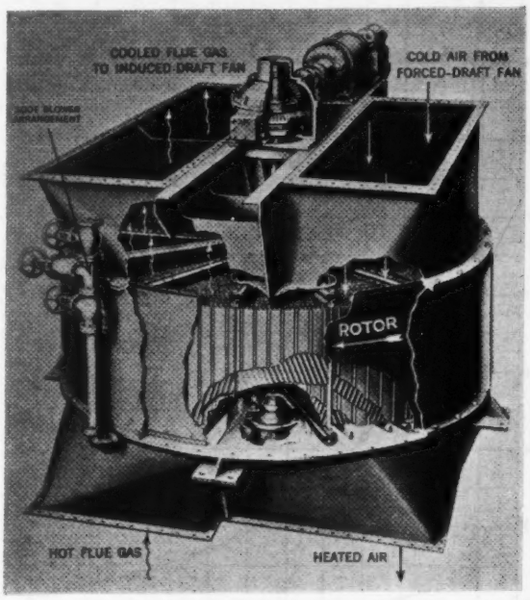
Courtesy Air Preheater Corporation.

FIGURE 16
Regenerative Air Preheater for Horizontal Gas and Air Flow.

and -outlet connections. The elements, as they rotate through the heating zone, are heated gradually by hot flue gas to substantially the incoming flue-gas temperature; and, as they rotate through the cooling zone, they are cooled gradually by the air being preheated. As a general rule, a larger proportion of the segments of the rotor is in the flue-gas flow than in the air flow to provide a greater cross-section for the flow of flue gas, so as to keep

to a minimum the gas draft losses through the preheater.

Each segment of elements is provided with sealing members, as shown in Figures 18 and 19, to prevent mixing the flue gases and air in adjoining segments of the cooling and the heating zones. The portion of the segment that is not exposed to either the flue-gas or the air streams acts as an additional seal between the flue-gas and the air streams, and as a purging section where the small amount of flue gas or air entrained in the respective segment is



Courtesy Air Preheater Corporation.

FIGURE 17
Regenerative Air Preheater for Vertical Gas and Air Flow.

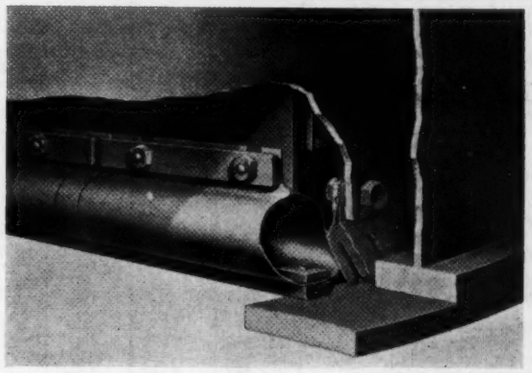
Courtesy Air Preheater Corporation.

FIGURE 18
Detail of Rotor Regenerative Air Preheater.

dissipated slowly into both streams so that contamination of either stream is practically negligible.

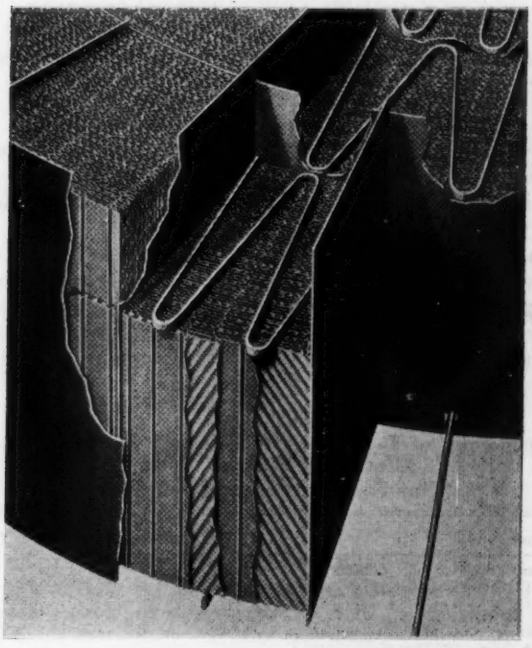
Figure 20 shows a two-layer construction of elements of the rotor, used when the temperature of the flue gases entering the preheater is above 1000° F. but below 1400° F. This construction corresponds to the two-section construction on plate and tubular preheaters shown diagrammatically in Figure 15. No outside cross-over for the air is required with this rotor construction; therefore, as many layers of different alloys as may be necessary with high gas temperatures to take care of the metal-temperature requirements may be used in this preheater. For example, with an entering flue-gas temperature of 1600° F., the hottest section of the elements may be made of stainless steel, the next section of 4- to 6-percent chrome, and the remainder of plain or copper-bearing steel.

With corrugated elements as used in this type of preheater, the draft loss is comparatively high, and both forced- and induced-draft fans must be used. The regenerative preheater is particularly effective



Courtesy Air Preheater Corporation.

FIGURE 19
Bottom Seal of Regenerative Air Preheater.



Courtesy Air Preheater Corporation.

FIGURE 20
Two-Layer Rotor Elements—Regenerative Air Preheater.

when high heat recoveries and close approach between high-temperature flue gas and preheated air are desired. With fuels that have a tendency to deposit soot, tar, and sulfur compounds in the cooler portion of air preheaters, this type of preheater, although built of undulated plate elements, will stay cleaner than the plate or tubular type, because the deposits—even if formed in the cooler section of the heating zone—will be burned off when the rotor re-enters the hottest section of this zone.

Regenerative air preheaters with stationary heat-

TABLE 3

Economics of Air Preheaters as Affected by Type of Preheater

(Flue-Gas Temperatures, 1,070° F.)

Operating conditions:

Capacity of heater, millions of Btu per hour delivered to oil	100
Gas per hour, lb.	181,000
Air per hour, lb.	173,000
Temperature of air leaving preheater, °F.	550
Fuel savings, millions of Btu per hour	31.9
Savings, dollars per year of 330 days, 24-hour day, at 10 cents per million Btu ($792 per million Btu per year)	25,265

	Plate Preheaters			
	Natural-Draft	Induced-Draft	Tubular	Regenerative
Capital Cost, Dollars:				
Preheater	12,515	10,400	7,095	7,830
Fans and motors	1,140	3,140	4,140	4,615
Duct work, insulation, foundations	6,900*	4,620	4,620	4,650
Total capital cost	20,555	18,160	15,855	17,095
Power Requirements, Horsepower Per Hour:				
Cold-air fan	22.5	22.5	32.3	27.5
Exhaust-gas fan	.....	28.8	78.0	48.1
Total power, horsepower per hour	22.5	51.3	110.3	75.6
Operating Cost:				
Power at $60 per horsepower-year	1,350	3,078	6,625	4,540
Insurance and taxes	950	830	715	770
Maintenance and repairs	1,260	5,158	1,250	1,300
Total operating cost	3,560	9,066	8,590	6,610
Net saving, dollars per year	21,705	20,107	16,675	18,655
Payoff time, in years	0.95	0.90	0.95	0.92
Payoff time, in months	11.4	10.8	11.4	11.0

* Includes cost of extra height of stack to obtain draft for preheater.

exchange elements are not used on petroleum heaters.

Economics of Air Preheaters

The profitability of an air preheater is determined by the relationship between capital expenditure for the air preheater, fans, motors, duct work, insulation, etc., the valve of the fuel saved, and the cost of saving this fuel. The value of the fuel saved is the actual sales value of the fuel. Non-salable fuels, even though of marketable quality, cannot be given any value in determining this relationship, except insofar as they reduce the use of salable fuel consumed in the plant. The cost of saving the fuel consists of the cost of power used by the fans, maintenance cost, repairs, extra supervision, if any, and the fixed charges on capital expenditure. A preheater which produces the greatest net savings and repays the capital expenditure in the shortest time (payoff time) is usually the most suitable for a given in-

TABLE 4

Economics of Induced-Draft Plate Air Preheaters as Affected by Type of Heater

(Flue-Gas Temperature, 1,070° F.)

Case	A	B	C	D
Net heat input to oil, millions of Btu per hour	25.0	50.0	75.0	100.0
Gas per hour, lb.	36,700	73,400	110,100	146,800
Air per hour, lb.	35,000	70,000	105,000	140,000
Fuel saving, millions of Btu per hr.	6.45	12.90	19.35	26.00
Savings, dollars per year of 330 days, 24-hour day, at 10 cents per million Btu ($792 per million Btu per year)	5,108	10,216	15,324	20,432
Capital Cost:				
Preheater (including erection)	2,773	4,706	6,450	8,530
Cold-air fan and motor	392	638	821	1,042
Exhaust-gas fan and motor	654	1,022	1,411	1,707
Duct work, insulation, foundations, labor	2,000	2,850	3,500	4,000
Total capital cost	5,819	9,216	12,182	15,279
Operating Cost:				
Cold-air fan, boiler, horsepower	5.0	11.3	16.5	19.3
Exhaust-gas fan, boiler horsepower	6.5	10.8	15.8	23.5
Total power, horsepower per hour	11.5	22.1	32.3	42.8
Cost at $60 per horsepower-year	690	1,326	1,938	2,534
Insurance and taxes	275	440	580	725
Maintenance and repairs	475	750	970	1,200
Total operating cost per year	1,440	2,516	3,488	4,459
Net Savings, dollars per year	3,668	7,700	11,836	15,973
Payoff time, in years	1.59	1.20	1.03	0.96
Payoff time, in months	19.1	14.4	12.4	11.5

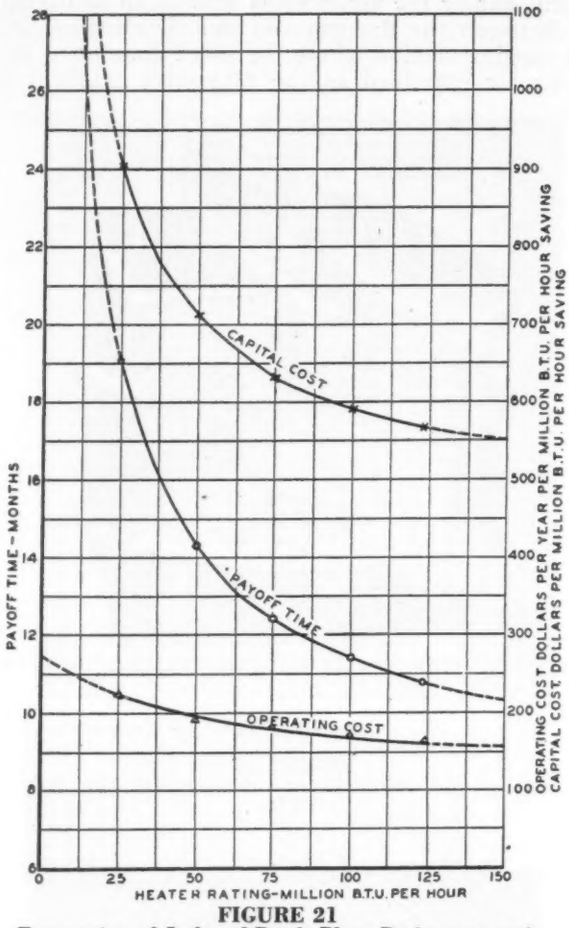
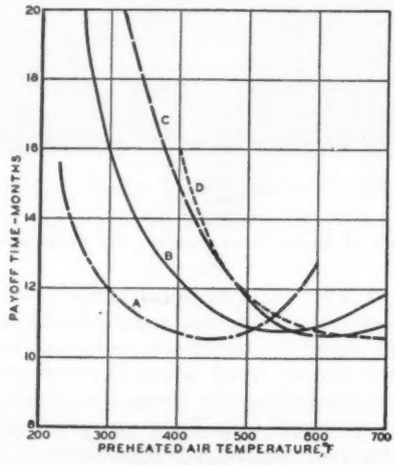

PAYOFF TIME - MONTHS
OPERATING COST DOLLARS PER YEAR PER MILLION B.T.U. PER HOUR SAVING
CAPITAL COST DOLLARS PER MILLION B.T.U. PER HOUR SAVING
CAPITAL COST
PAYOFF TIME
OPERATING COST
HEATER RATING-MILLION B.T.U. PER HOUR

FIGURE 21

Economics of Induced-Draft Plate Preheaters with Change of Capacity—Flue-Gas Temperature, 1070° F; Preheated-Air Temperature, 550° F.



A—Plate, Natural-Draft.
B—Plate, Induced-Draft.
C—Tubular.
D—Regenerative.

FIGURE 22

Change in Payoff Time of Different Types of Preheaters with Change of Preheated-Air Temperature—Flue-Gas Temperature, 1070° F.

TABLE 5

Change in Economics of Plate-Type Air Preheaters with Change of Preheated-Air Temperature

CASE	1		2		3		4
	Natural-Draft	Induced-Draft	Natural-Draft	Induced-Draft	Natural-Draft	Induced-Draft	Induced-Draft
Gas per hour, lb.	200,000		187,000		181,000		173,000
Air per hour, lb.	192,000		179,000		173,000		166,000
Temperature of air leaving preheater, °F.	250		450		550		700
Fuel savings, millions of Btu per hour	13.2		26.0		31.9		39.3
Savings, dollars per year of 330 days, 24-hour day, at 10 cents per million Btu ($792 per million Btu per year)	10,454		20,592		25,265		31,226
Capital Cost:							
Preheater (including erection)	4,076	3,536	8,880	7,380	12,515	10,400	17,750
Cold-air fan and motor	1,165	1,165	1,140	1,140	1,140	1,140	1,125
Exhaust-gas fan and motor	.....	4,810	.....	2,465	.....	2,000	1,740
Duct work, insulation, foundations, labor	2,870	3,100	3,600	4,225	4,100	4,620	4,950
Additional height of stack	1,400	.....	1,900	.....	2,800	.....	.....
Total capital cost	9,511	12,611	15,520	15,210	20,555	18,160	25,565
Operating Cost:							
Cold-air fan, boiler horsepower	20.0	20.0	22.5	22.5	22.5	22.5	15.5
Exhaust-gas fan, boiler horsepower	.....	28.8	.....	25.0	.....	28.8	26.4
Total power, horsepower per hour	20.0	48.8	22.5	47.5	22.5	51.3	41.9
Cost at $60 per horsepower-year	1,200	2,928	1,350	2,850	1,350	3,078	2,514
Insurance and taxes	425	580	715	700	950	830	1,010
Maintenance and repairs	450	500	900	975	1,260	1,250	1,900
Total operating cost per year	2,075	4,008	2,965	4,525	3,560	5,158	5,424
Net savings, dollars per year	8,379	6,446	17,627	16,067	21,705	20,107	25,802
Payoff time, in years	1.14	1.96	0.88	0.95	0.95	0.90	0.99
Payoff time, in months	13.7	23.5	10.6	11.4	11.4	10.8	11.9

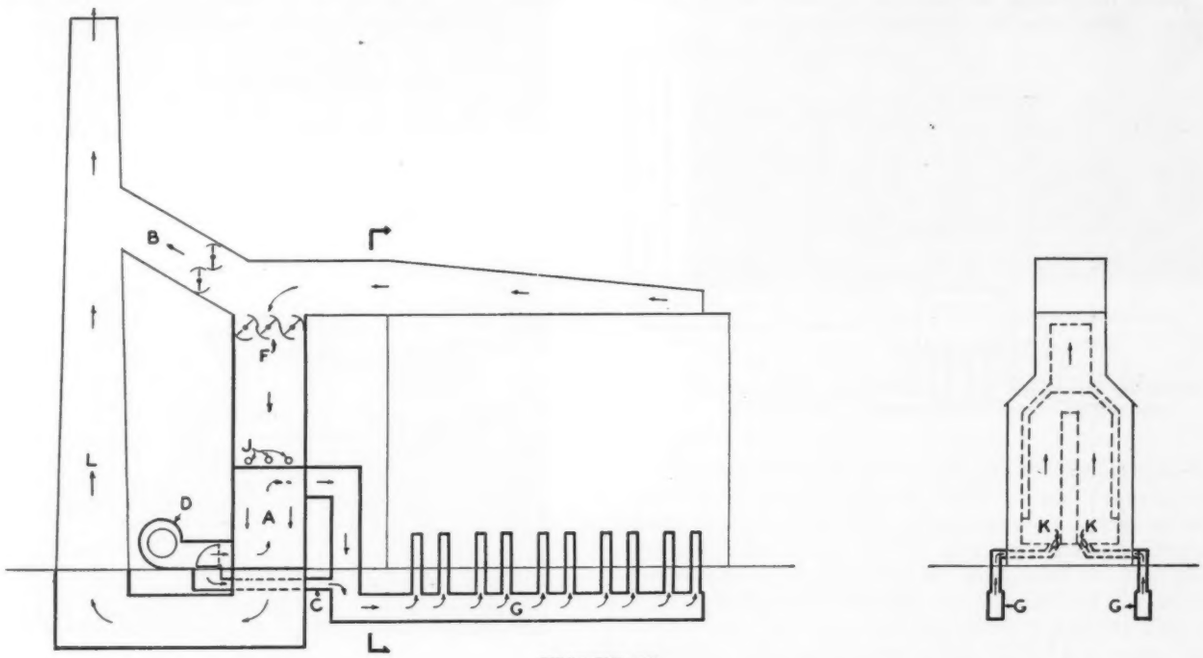


FIGURE 23

Schematic Arrangement of Recuperative Air-Preheater Installation on Heater with Top Flue-Gas Discharge and Upward Firing through Bottom of Heater.

stallation. Net savings alone, or payoff time alone, is not always the proper criterion in determining the profitability of an air preheater.

Table 3 is a tabulation of economics of four types of air preheaters intended for identical service. The capital expenditure varies from a minimum of $15,855 for the tubular to a maximum of $20,555 for the natural-draft plate preheater. On the basis of payoff time alone, the induced-draft plate preheater is the most profitable of the four, and could be chosen to obtain the quickest return on the investment. However, at the end of the payoff period the natural-draft plate preheater will be saving approximately $5000 per year more than the tubular preheater, and approximately $1600 per year more than the induced-draft plate preheater—so that, under the conditions specified and with the short payoff time for all four preheaters, the natural-draft plate preheater is the most profitable.

The profitability of air preheaters of a given type, particularly the relative profitability of preheaters of different types, is affected by the preheater size and the fuel savings desired. Table 4 and Figure 21 show the change in economics of induced-draft plate preheaters with change of capacity of the heater on which the preheater is to be installed. Table 5 shows the change in economics of natural-draft and induced-draft plate air preheaters for a heater of a given capacity as the temperature of the preheated air is varied. On the basis of payoff time, 450° F. is the optimum preheated-air temperature for the natural-draft preheater and 550° F. for the induced-

draft. With natural draft, an air preheater for 700° F. preheated air has to operate with such low velocities—due to the limited draft available with the low-temperature flue gases leaving the preheater—that, with the low-temperature differences prevailing under the operating conditions, the preheater becomes unreasonably large and expensive. Therefore, the economics of the natural-draft air preheater is indication of the optimum air-preheat temperature for each type. Operation of any of these preheaters much above the optimum air-preheat temperature may make their use unprofitable.

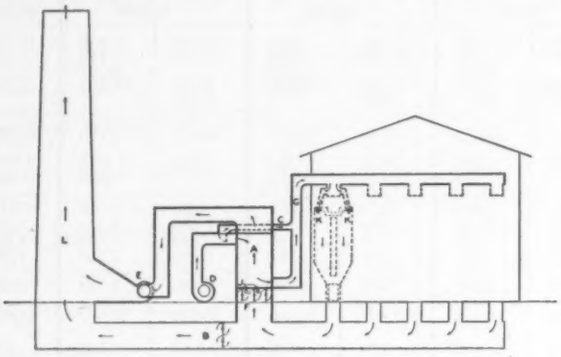


FIGURE 24
Schematic Arrangement of Recuperative Air-Preheater Installation on Heater with Bottom Flue-Gas Discharge and Downward Top Firing.

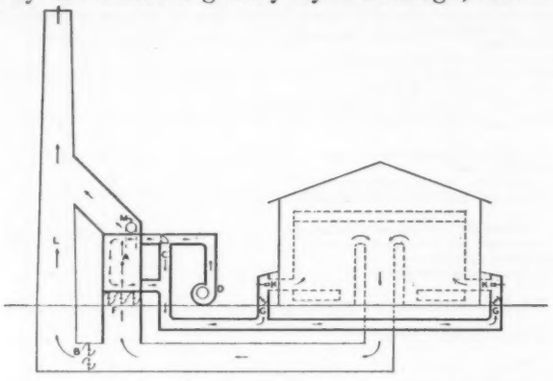


FIGURE 25
Schematic Arrangement of Recuperative Air-Preheater Installation on Heater with Bottom Flue-Gas Discharge and Horizontal Firing through Side Walls.

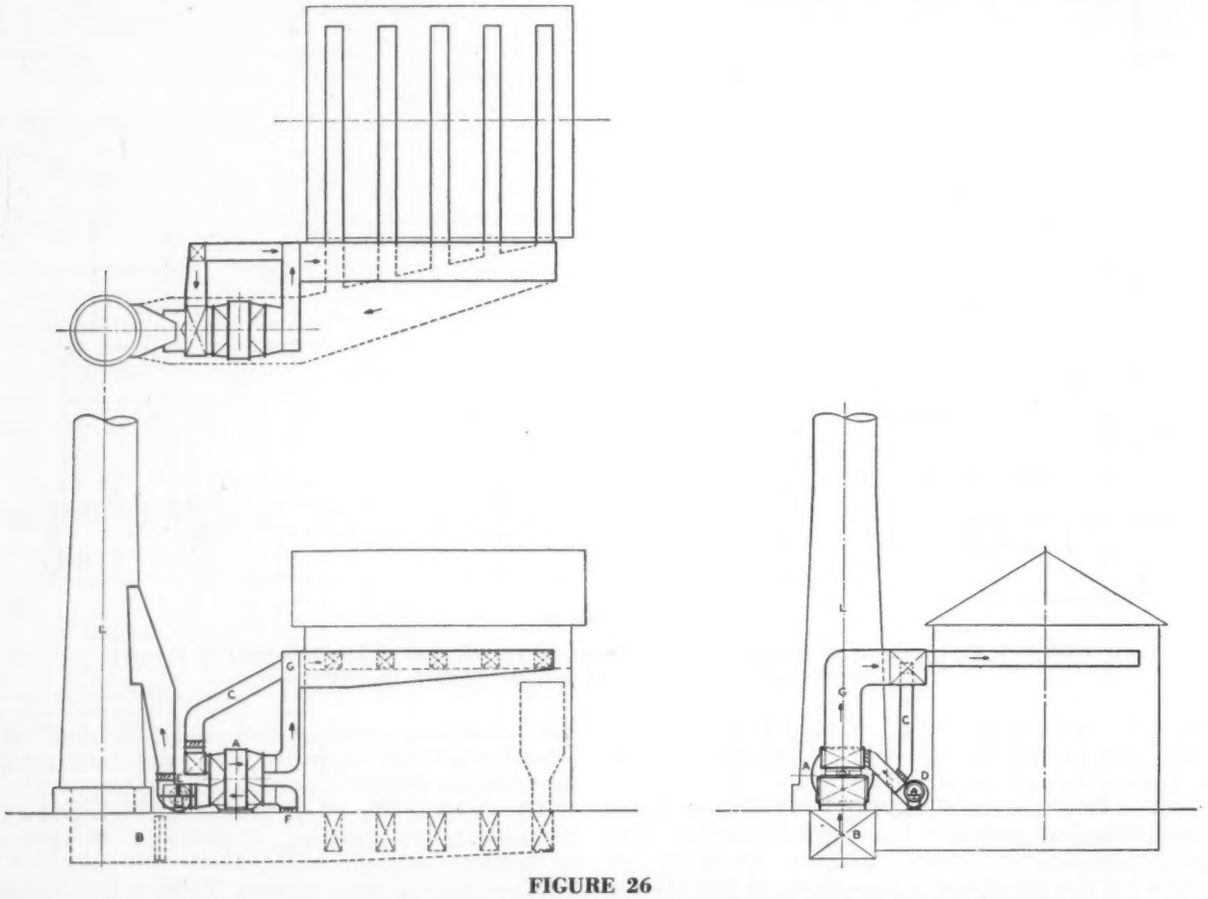


FIGURE 26
Schematic Arrangements of Regenerative Air-Preheater Installation for Heater as in Figure 24.

Design and Operating Factors

The operation of an air preheater and its profitability are affected greatly by the design, the manner of installation, and the care used to eliminate—or at least to minimize—the factors which interfere with the efficiency and the continuity of the operation of the preheater under the conditions prevailing in the refinery. The greatest of these factors are corrosion of the preheater elements and fouling of the gas passages of the preheater. The preheater, there-

omitted for case 4 of the comparison. Figure 22 shows the effect of variation in temperature of preheated air on the payoff time of four types of air preheaters for a heater of a given size. The lowest point in the payoff-time curves coincides with the point of greatest net savings obtained with this size preheater, so that the curves may be used as an

fore, should be designed to operate with metal temperatures above those which will result in condensation of the sulphur compounds and the tarry materials in the products of combustion which cause the corrosion and the fouling. With heavy liquid fuels, and with high-sulfur liquid and gaseous fuels, it may be necessary to limit the heat recovery below that which can be obtained with clean-burning nonsulfurous fuels to maintain the temperature of the flue gas and of the elements above the troublesome range.

Even if a preheater is designed for normal operation at temperatures above the corrosion and fouling

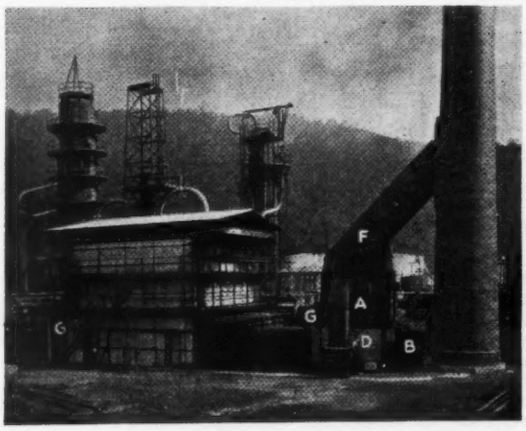


FIGURE 27
Arrangement of Natural-Draft Plate Air Preheater—Bottom Flue-Gas Discharge; Side Firing.

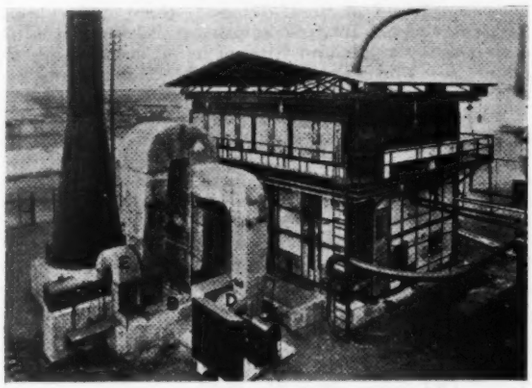
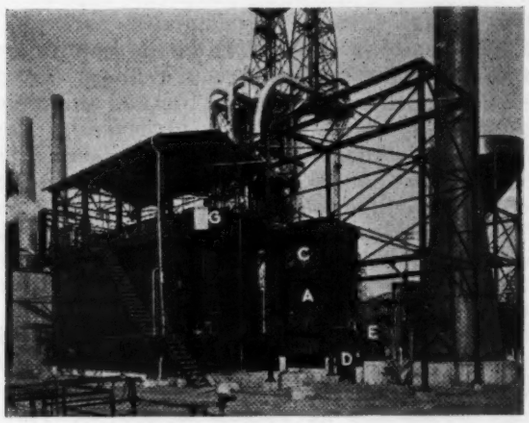


FIGURE 28
Arrangement of Tubular Air Preheater with Forced- and Induced-Draft Fans—Bottom Flue-Gas Discharge; Side Firing.

point, it will be subjected to corrosion and fouling on the startup, unless provided with by-passes to cut the preheater out of service until the corrosion and fouling temperatures have been passed. Many recent air-preheater installations are provided with automatic means to by-pass the flue gas around the preheater until the flue gas exceeds a certain minimum temperature and, after this gas temperature has been reached, to admit air to the air preheater only in sufficient quantity to maintain the exit-gas temperature above the desired minimum while the heater is being warmed up.

Although most of the corrosion and a good part of the fouling may be eliminated in this manner, mechanical means may be required to clean the preheater gas passages while the heater is in operation. Soot blowers, scraper chains, and vibration bars are the most common means used.

Preheaters usually are designed with elements made of materials that are satisfactory only for normal operating conditions. The preheater, therefore, should be protected against abnormal conditions, such as still fires. During a fire, the air supply to the burners is cut off, eliminating the cooling medium for the elements of the preheater while much higher temperature gases are passing around them. The air preheater, therefore, should be provided with a quick-operating interlocking arrangement of dampers to by-pass the preheater and to shut off the flow of gases into the preheater in order to avoid damage to the elements even with a short fire.



Courtesy Foster-Wheeler Corporation.

FIGURE 29
Arrangement of Tubular Air Preheater—Bottom Flue-Gas Discharge; Downward Top Firing.

Figures 23 to 26, inclusive, show typical schematic arrangements of installations of air preheaters on heaters with different relationship of the point of firing and the point of flue-gas withdrawal. The relationship of flue gas and air flow, and the use of natural or induced draft, are not specific for the arrangements shown, but are included to show the most common arrangements used with any type of air preheater and any type of heater.

Figures 27, 28, and 29 are photographs of typical arrangements on actual installations. The pertinent components of the arrangements, as shown in Figures 23 to 29, inclusive, are marked as follows:

A—Preheater.
B—Flue-Gas By-Pass
C—Air By-Pass.
D—Forced-Draft (Cold-Air) Fan.
E—Induced-Draft (Exhaust-Gas) Fan.
F—Emergency Shutoff Damper.
G—Preheated-Air Duct.
J—Soot Blower.
K—Burners.
L—Stack.
M—Scraper Chains.

Generation of Steam

As a Factor in Modern-Refinery Heat Economy

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The Lummus Company

THIS paper discusses the recovery of heat in various refinery operations by utilizing it for steam generation. With the advance in modern thermal processes which employ increased temperature and pressure levels and also in modern catalytic processes, the removal of large amounts of excess heat existing in the system by using this heat for generating steam offers a simple, flexible and economical solution to the refiner, especially when the cooling-water and steam conditions are not satisfactory.

Aside from employing heat exchangers on a number of hot streams available within the process system, the installation of surface in the convection section of oil heaters under certain conditions has been employed successfully for steam generation, particularly on heaters requiring expensive alloy material for tubes and fittings in oil service. Steam generation and its effect upon selection of pumps and reduction in utilities consumption are outlined.

The selection of the type of steam-generating equipment to be employed depends on the number, temperature, and pressure level of various hot streams available from the particular operation, and also upon the cost of tubes and headers required in the oil heaters.

Typical installations of steam generation as incorporated in asphalt distillation, thermal polymerization, and combination cracking units are discussed and illustrated by flow diagrams and tables.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

THE recovery of heat is one of the important factors affecting the profitability of refinery operation. Operations such as distillation, thermal and catalytic cracking, polymerization, solvent refining, dewaxing, and many more processes are dependent upon an outside heat source. With the trend at the present time in the direction of improved-quality motor fuels and lubricating oils, many newly developed processes require still more heat, which means that heat recovery will have not only continuing but increasing interest for the refiner.

The transfer of heat from a hot stream within or leaving a process unit to a cold stream entering the unit has been the basis for most of the heat-exchange equipment at present employed. This has led to the widespread use of liquid-liquid and vapor-liquid exchangers to effect fuel savings by reducing the external heating requirements. The extent to which hot streams may be used economically for heating cold streams is determined by comparing the cost of installing and maintaining equipment for heat recovery with the saving in fuel cost which results. There is always a point of economic balance above which the additional cost of heat exchange will exceed the saving in fuel. The same principle can be applied to heat recovery from hot gases leaving direct-fired heating units, because the added cost of heating surface for increasing the efficiency of fired heaters eventually will reach a point where it overbalances the resultant saving in fuel.

In heat exchange between hot and cold streams, the cold stream can be raised economically only to a certain temperature level, so that in most cases additional heat to the cold stream must be supplied by direct-fired heating. Hot streams, after having given up some heat through heat exchange with cold streams, still are at a fairly high temperature level, and, hence, must be cooled to the desired temperature by an external cooling medium, i.e., water. There are also cases in which the maximum temperature to which the cold stream can be heated is limited by the necessity of avoiding vaporization or for other reasons. The net result is that large quantities of heat must be removed by cooling water, with attendant cost of water-pumping equipment, cooling-tower equipment, etc. Because the cooling-water situation at a great many refineries is far from ideal, the cumulative effect is higher operating cost. Coincidental with added cooling-water requirements is the need for more steam for pump drives and sundry process uses. One solution of the situation outlined is to recover much of the heat which otherwise would be dissipated to cooling water or to stack gases by employing it for the generation of steam.

This practice is not new, but in recent years many developments and modifications have been made which have increased its value and usefulness. The more general acceptance of steam generation for heat recovery has been accelerated by the increased temperature and pressure level and high internal cycle employed in thermal processes, and also by the many new catalytic processes which require the removal of a great amount of excess heat created by process requirements. The trend of increased temperature levels and excess heat available in modern

refining practice leads to a greater demand for both cooling water and steam, which makes heat recovery by steam generation most attractive.

For refinery units of large capacity, a factor which must be considered in intelligent design is the need for a certain amount of flexibility as regards charging material and operation for market requirements.

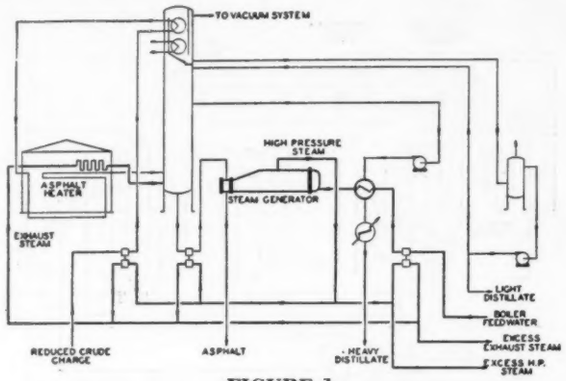


FIGURE 1
Flow Diagram—Asphalt Distillation Unit.

There are a few locations wherein a constant supply of uniform-quality crude oil can be counted on, but a great many refiners must process different crudes in various proportions, depending on the source of crude supply and changes in market conditions. For a combination selective thermal cracking unit, this may mean a considerable increase in light-end cracking when a paraffinic-type crude with high gasoline content of low octane number is available or, on the other hand, it may shift the cracking load to viscosity breaking and heavy-oil cracking if a heavy-naphthenic or asphaltic-type crude must be run. Such a change in cracking load has a corresponding influence on the heat-recovery system of such a unit and, rather than provide for flexibility by the installation of considerable over-surface in heat equipment on the several hot streams which will vary the most, it has been found advantageous to install a steam-generating system having multiple elements that allow the desired flexibility. These elements can be made uniform in size and so manifolded that they may be shifted from one hot stream to another as shifts in heat load occur. The overall heat recovery from such a system normally is reasonably constant in spite of considerable variation in individual hot streams, so that the over-surface requirements can be kept to a minimum in comparison with heat exchange between hot and cold oil.

In addition to shell-and-tube type units, the installation of steam-generating surface in the convection section of direct-fired heating units has been employed successfully and economically. Tubes and fittings for oil service often are of expensive alloy material for withstanding the temperature and pressure conditions encountered; and, as higher heat absorption rates are obtainable from radiant or semi-radiant tubes than from convection tubes, any alternate method of recovering useful heat from hot gases by convection tubes becomes attractive. In some cases the savings effected by using radiant instead of convection tubes for oil service have paid for the cost of installing steam-generating surface in the convection section. The effect of any variation in oil-heating load upon the heat available in hot gases is absorbed readily by a steam-generating coil in the convection section.

Selection of the type of steam-generating equipment for heat recovery depends on the steam characteristics desired and on the particular operation under consideration. This is influenced by the number and temperature and the pressure level of various hot and cold streams, their respective heat transfer rates and fouling factors. Most steam generators installed are of the circulating type rather than the once-through type, so that heat is transferred from the tube wall through a boiling-water film accompanied by high velocities on the water side. This mechanism makes possible the economical recovery of heat from such hot streams as tar, asphalt, and other residual oils wherein fouling of heat-exchange surface by the hot medium is rapid. Inasmuch as fouling is confined to one side only, the foul medium can be put through the tubes and cleaning made easier. In case sufficient surface is indicated to warrant installing several units, cleaning can be carried out easily during operation by by-passing the fouled unit, cleaning it in place, and subsequently putting it back in service.

To illustrate the potentialities of steam generation, we shall consider typical installations incorporated in such refinery operations as asphalt distillation, thermal polymerization or polyforming, small-scale cracking, and large-scale combination cracking.

Asphalt Distillation Unit

Steam-generation equipment added to an asphalt distillation unit can be taken as a typical example of the simplest type of system. Inasmuch as the asphalt product is normally a large percentage of the reduced-crude charging stock, and as this stream is at a high temperature level, a large amount of heat is available for generation in one stream. The poor overall heat-transfer coefficient between asphalt product and reduced-crude feed, plus fouling conditions which prevent maintenance of clean transfer rates, also makes generation of steam attractive. A process factor favoring steam generation in this type of distillation unit is the positive control of the cooled temperature of the asphalt stream. With a water-cooled coil in such service, there is always the danger of too much cooling, with consequent plugging of the coil by solidified asphalt. With boil-

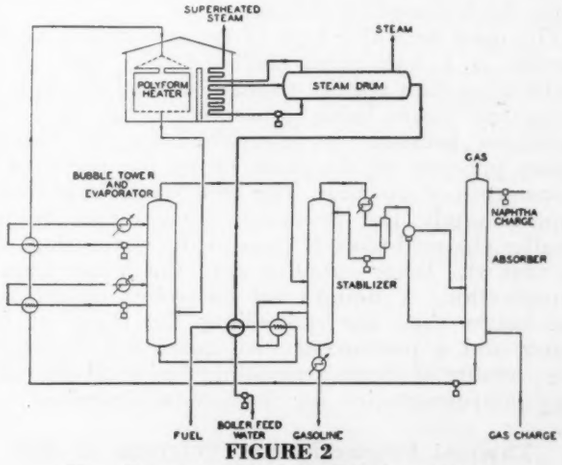


FIGURE 2
Flow Diagram—Naphtha Polyform Unit.

ing water as cooling medium, the cooled-asphalt temperature is controlled automatically within a few degrees. A steam-generating system fits in well with an asphalt plant, because the steam requirements for this type of plant are quite large—including, besides steam for pumps and process steam, steam for tank heating and steam tracing of asphalt lines.

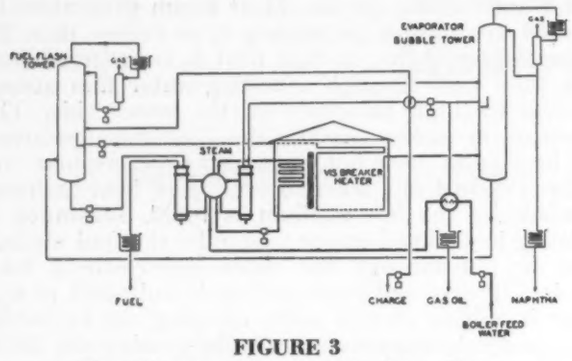


FIGURE 3
Flow Diagram—Viscosity-Breaking Unit.

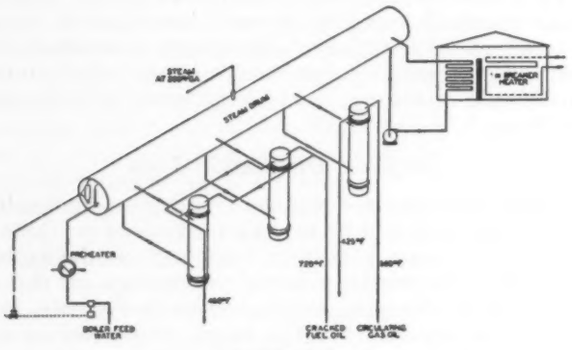


FIGURE 4
Steam Diagram—Viscosity-Breaking Unit.

Figure 1 is a simplified flow diagram of an asphalt distillation unit incorporating generation of steam from the hot-asphalt stream.

The most desirable type of generator unit for this service is a horizontal shell-and-tube unit of the kettle type with the hot asphalt flowing through the tubes and steam being generated in the shell. The generator pressure is determined by the existing steam pressure of the plant or by the pressure requirements of the unit. The feed water is heated to approximately the generator temperature from a smaller stream before it goes to the generating unit, so that the latter supplies only the latent heat of vaporization. A liquid-level controller installed on the kettle shell for controlling the input of feed water and a pressure-control valve for controlling the pressure of steam generated provide all the necessary instrumentation for the system described.

Thermal Polymerization, Polyform or Gas Reversion Units

Thermal polymerization, polyform or gas reversion units afford a good example of the type of plant characterized by high temperatures and high pressures in the fired heater coils, but with less waste heat in circulating streams at temperature levels attractive for steam generation than is the case in conventional thermal cracking units.

Figure 2 shows a simplified flow diagram of such a process unit. Cold charge is preheated readily by heat exchange against circulating hot streams of the combined evaporator and bubble tower, so that convection-section heating is not attractive.

Because surface in the radiant section of an oil heater will absorb approximately three times the

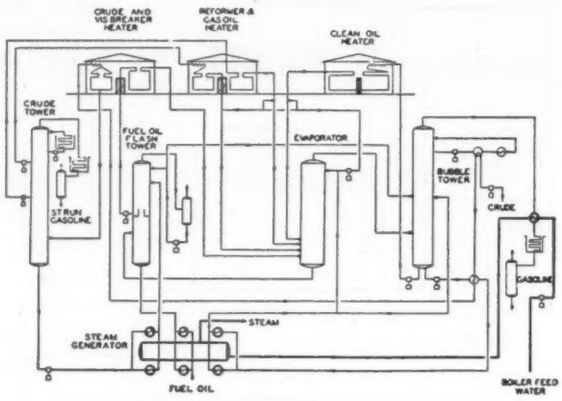


FIGURE 5
Flow Diagram—Combination Cracking Unit.

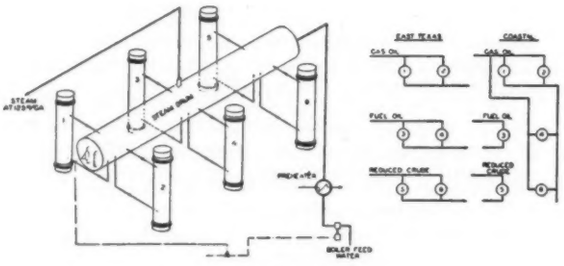


FIGURE 6
Steam Diagram—Combination Cracking Unit.

amount of heat per square foot as surface in the convection section, the saving in expensive tubes and fittings by putting all surface for oil heating in the radiant section usually will pay for carbon-steel tubes and fittings installed in the convection section for steam generation. A portion of the convection section sometimes is utilized for steam superheating as well as for steam generation.

The steam-generating system for this type of unit consists of a separating drum, heater tubes in the convection section, a water-circulating pump, and the necessary instruments. Water is circulated from the bottom of the drum through the heater tubes at a rate considerably higher than the rate of generation in order that at no time will there be complete vaporization in the tubes. The mixture of steam and water is returned to the drum, where the steam and water are separated by means of baffles and a dry pipe. The feed water is preheated practically to the separating-drum temperature by exchange with an available hot-oil stream. The instrumentation required consists only of means for controlling water circulation, feed-water supply, and steam pressure.

With this arrangement, considerable steam is generated at low cost, because the total investment cost of the heater, including steam-generating tubes, is no higher than if oil alone were heated. The amount of heat recovered by steam generation and super-

TABLE 1
Steam-Generation Data for Large Combination Cracking Unit

(Note: Steam generated at 125 psi, gage)

	East Texas Crude	Coastal Crude
Gas oil:		
Quantity, lb. per hour	230,000	351,100
Heat removed, Btu per hour	10,700,000	31,220,000
Cooling range, °F.	485-425	560-425
Steam produced, lb. per hour	11,800	34,400
Number of bundles	2	4
Fuel oil:		
Quantity, lb. per hour	100,700	65,600
Heat removed, Btu per hour	17,300,000	10,000,000
Cooling range, °F.	710-415	700-400
Steam produced, lb. per hour	19,100	11,000
Number of bundles	2	1
Reduced crude:		
Quantity, lb. per hour	136,600	67,000
Heat removed, Btu per hour	16,450,000	8,370,000
Cooling range, °F.	605-420	590-405
Steam produced, lb. per hour	18,100	9,200
Number of bundles	2	1
Total steam produced, lb. per hour	49,000	54,600

heating with this arrangement is about 25 percent of the heat absorbed by oil, and is enough to operate the main charge pumps of the plant. Steam at pressures up to 450 psi, gage, has been generated in a system of the type shown.

Small Cracking Plant

A small cracking plant can be taken as an example of an installation with more than one source of waste heat available in hot-oil streams. Also, depending upon the particular case, it may or may not be advisable to include generation from tubes in a convection section of a heater. Inasmuch as a small cracking plant generally is designed for only one charging stock and has little flexibility, both the plant itself and the steam-generating system must be simple.

There are several possible oil streams available at high enough temperatures and of such size that steam generation is attractive. If the feed to the unit is crude oil, a fuel-oil stream of from 15 to 40 percent of crude is available at a temperature of from 650 to 700° F. The circulating gas-oil stream used for quench and reflux varies greatly with the type of process unit, but is often the largest hot stream available. This stream is at a temperature of about 700° F.; and, after having been used for crude preheat, is still available at a temperature of 550 to 600° F. for steam generation.

Figure 3 shows a simplified flow diagram of a small-capacity viscosity-breaking unit. As the charging stock in this case is hot reduced crude, there is no liquid preheating problem, and the total heat of both circulating reflux and fuel-oil streams can be used for steam generation.

Figure 4 shows the general arrangement of the steam-generating system itself. This particular installation includes steam generation in the convection section of the heater as well as from the hot-oil streams. The equipment includes a horizontal separating drum, a water-circulating pump, tubes in the convection section as described previously, and vertical shell-and-tube units attached to the separating drum. The hot-oil streams are circulated through the tubes, with boiling water circulating through the shell side of the bundles shown. Feed water, which has been preheated by a small hot stream, is fed into the drum to maintain liquid level. Such a system normally produces steam at pressures of 150 to 200 psi. If desired, steam may be generated at one pressure from the hot-oil streams and at a higher pressure from heater tubes—which arrangement, of course, requires two separating drums and two sets of instrument control.

Large Combination Cracking Unit

A large-capacity combination cracking unit usually is designed for flexibility to meet variations in charging stocks and market conditions. Several sources of waste heat are available in liquid streams at temperature levels suitable for generation of steam. The fired heating units are large; and, as some of the heater charge streams are at high temperatures, steam can be generated also by employing the convection sections of these heaters. Reduced crude is available to the extent of approximately 30 to 60 percent of the crude charge at a temperature of 550 to 600° F., fuel oil to the extent of 15 to 40 percent at 650 to 700° F., and circulating gas oil at approximately 500 to 600° F. These are approximate levels after economical crude preheating.

The elements of such a modern selective cracking unit are shown diagrammatically in Figure 5. As will be seen, there are six coils for crude preheating, reforming, viscosity breaking, and virgin and recycle gas-oil cracking. The process flexibility provided by such an arrangement makes it essential to provide similar flexibility in the steam-generating system. This has been accomplished by an arrangement such as that shown in Figure 6, which is a unique development of The Lummus Company. The combination of steam separating drum and attached vertical shell-and-tube bundles is similar to previously described systems. However, by providing multiple units and a system of manifolded hot-oil piping, as

TABLE 2
Steam-Generation Data for Typical Refinery Units

Type of Unit	Asphalt Distillation	Naphtha Polyform	Small Cracking	Large Combination Cracking
Flow diagram	Fig. 1	Fig. 2	Fig. 3	Fig. 5
Capacity, bbl. per day	4,000	13,000	5,000	22,000
Steam pressure, psi, gage	120	150	200	125
Steam from hot streams, lb. per hour	4,500	12,000	10,600	49,000
Steam from convection tubes, lb. per hour	....	48,000*	7,400	....
Total steam generated, lb. per hour	4,500	60,000	18,000	49,000
Total steam requirements, lb. per hour	3,500	48,000	8,000	58,000
Total electricity requirements, kw.	30	400	85	1,100
Total heater duty, millions of Btu per hour	13.3	200.0	45.5	245.0
Heater steam generation, percent of total heater duty	....	30.0	20.0	....
Hot-oil steam generation, percent of total heater duty	40.0	7.0	28.0	24.0
Reduction in cooling-water requirements (30 °F. rise), gal. per min.	360	950	850	3,900

* 100° F. superheat at 125 psi.

TABLE 3
Economics of Steam Generation

Type of Unit	Asphalt Distillation	Naphtha Polyform	Small Cracking	Large Combination Cracking
Flow diagram	Fig. 1	Fig. 2	Fig. 3	Fig. 5
Additional investment, dollars	3,980	32,600	14,250	42,200
Savings in water circulation, dollars per month	150	420	360	1,680
Value of steam generated, dollars per month	840	11,200	3,400	9,200
Cost of additional fuel, dollars per month	....	1,500	600	....
Net return, dollars per month	990	10,120	3,160	10,880
Payoff, months	4.0	3.2	4.5	3.9

shown in Figure 6, it becomes possible to compensate for great variations in hot-oil stream quantities and temperatures without having to install excessive shell-and-tube surface. The advantage of such a multiple-unit system clearly is indicated by the operating data of Table 1. We find that, in spite of the variations shown, the total amount of steam generated is relatively constant and the surface installed is operating at good efficiency. Although the actual installation from which these data were obtained did not include steam-generating tubes in the heater, approximately 50,000 pounds per hour of additional steam could have been produced.

The division of steam-generating equipment into a high- and a moderate-pressure system may be worthwhile for this size installation, depending upon the circumstances. Also, in cases wherein very rapid fouling occurs or wherein variations in hot-stream flow and temperature are even greater than shown, the use of properly manifolded spare shell-and-tube bundles should be considered.

Conclusions

We have indicated in this paper some of the many applications for steam generation in refinery operations, all of which were the result of studies made to improve heat economy. What this means in terms of utilities requirements is shown by Table 2. For example, we find that the asphalt distillation unit is more than self-supporting as regards steam for pumps, vacuum jets, and fuel-oil atomization—with ample exhaust steam available for process use. The naphtha polyform unit, with high-pressure heater charge pumps can depend upon a large and uniform steam supply, with most of this steam at 100° F. superheat. The electric load indicated results from the choice of motor-driven centrifugal pumps for most low-head services, making this plant more than self-sufficient as regards steam-driven pumps. As can be seen from Table 2, the quantity of steam generated amounted to 60,000 pounds per hour for this unit. Conditions for the small cracking unit are similar to those for the asphalt distillaton unit. The economics of electric power and steam cost dictated the choice of drivers for pumps in the large combination unit. The amount of steam generated proved sufficient for normal operation, although a demand on the refinery boiler plant of 9000 pounds of steam per hour is indicated as a maximum condition. The reduction in cooling-water requirements for all examples also merits attention. If we note the relationship of heat recovered by steam generation from hot streams to the external heat added to oil, we can obtain a measure of reduced cooling-water requirements, because external heating requirements and external cooling requirements are approximately the same. Steam generated from hot-oil streams, expressed as percent of the total heater duty, may be as high as 40 percent, as indicated by Table 2.

Table 3 shows the economics of steam generation applied to the refinery units taken as typical examples.

Under the heading "additional investment" is included the cost of all extra equipment required, such as surface in heaters, shell-and-tube equipment, drums, instruments, pumps, piping, etc.

The value of steam is taken as 26 cents per 1000 pounds; of fuel, as $1.00 per barrel; and of water, as 1 cent per 1000 gallons. The indicated payoff period is seen to be very short, ranging from 3 to 4½ months.

We have shown the value of steam generation as a means of recovering waste heat from liquid streams and hot furnace gases for a number of typical refinery operations. We have discussed the flexibility and process control obtainable from such installations, and the factors which determine the choice of the specific type of equipment employed. It should be noted that operations in many existing plants can be made more economical by heat recovery through generation of steam.

Fuel Economy in Refineries

D. C. LAWRENCE
The Texas Company

ONE of the largest single items of direct operating expense for refinery operations is fuel. Depending upon the type of operations carried on in a particular oil refinery, fuel costs probably will be in the range of 20 to 30 percent of total direct operating expense, excluding overhead costs. Because fuel costs represent such a large percentage of total operating cost, it is a very attractive field to attack in an effort to reduce operating expenses.

Fuel usage in a refinery may be considered under two classifications:

1. Fuel consumed to provide necessary utilities, such as steam, electric power, fire protection, etc.
2. Fuel used directly in processing refinery products.

When all power is generated in the refinery, the fuel cost for utilities will be in the range of 40 to 50 percent of the total refinery fuel cost. Fuel used directly for process work is, of course, in about the same order of magnitude.

The quantity of fuel required to provide utilities for a refinery may be reduced by:

1. More efficient generation of utilities.
2. More efficient usage of utilities by the various consumers.

Generation of Utilities

Due to the centralization of generating equipment and personnel, the economic production of utilities does not present as complicated a problem as does the economical usage of utilities by a great number of varied and widely scattered processes.

Fuel consumed for the generation of utilities is burned primarily under boilers or steam generators. For this reason, any reduction in utilities will represent a reduction in fuel consumed. The steam may be generated at the pressure required for process drives or process use, in which case it goes direct from the boiler to the steam-distribution system. If electric-power generating equipment is installed, the steam would be generated at an economical pressure and temperature to provide power requirements, and turbo generators would be used to reduce the pressure and temperature at which steam was generated consistent with process requirements.

New steam- and power-generating plants would be designed for maximum economical efficiency, consistent with steam and power balance and price of fuel.

Air heaters and economizers would be utilized to lower stack-gas temperatures. Open feed-water heaters using low-pressure steam, or closed high-pressure heaters exchanging heat from blowdown, or other sources of refinery waste heat would be used to raise the temperature of the feed water going to the boiler.

BECAUSE fuel costs represent 20 to 30 percent of total direct operating costs in an oil refinery, it is a very attractive field to attack in an effort to reduce operating expenses.

Fuel is used to generate utilities and for process work. Fuel consumption is divided about equally between utility generation and process work.

Fuel costs for utilities can be kept to a minimum by efficient generation and usage.

Inasmuch as generating facilities and the necessary operating personnel are centralized and operation is routine, the efficient generation of utilities should not present any particular problem.

Usage of utilities is, however, a quite different problem. Products from the various processes change with consumer demand, seasons, etc., which vary the utility requirements, changing loadings on utility systems, individual drives, etc. To maintain a high efficiency in usage, constant modifications and changes are required.

Fuel consumed by the processes may be reduced by efficient heater design, by heat exchange from hot streams to incoming charge, to reboilers, to steam generators, to boiler feed water, etc.

In other words, all available heat should be used, if economically possible, for some useful purpose rather than absorbed by the plant water supply.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

Older generating plants, in many instances, can be replaced or supplemented with equipment of modern design at very attractive rates of return on the investment cost. This is due to increased efficiency of the steam-generating equipment and the generation of low-cost by-product electric power.

New Power Plant at Port Arthur Refinery

A recent installation of this nature was made in one of our refineries, which is located at Port Arthur, Texas, and which has been discussed in articles appearing in several technical magazines.

Before the new power plant was built, utilities for the refinery had been supplied by a power plant generating steam at 215 psi from boilers having a capacity of 7440 horsepower. Steam from these boilers was supplied to three 3000-kw 2400-volt turbo-generators —two of which exhausted to 27 inches mercury vacuum, and one exhausted against 15 psi back pressure. Any surplus steam not required by the turbo-generators went to the plant steam-distribution system through a pressure-reducing and desuperheating station. The remainder of the refinery steam requirements was supplied from 150-psi boil-

ers aggregating 20,000 horsepower. Power generation was supplemented with purchased power.

Because refinery operations were to be increased, a study of existing steam- and power-generating facilities was made, and it was found that a high-pressure power plant generating steam at 600 pounds and exhausting at 150 pounds offered the greatest economy. Installation of the new power plant made possible attractive economies, due to increased efficiency of the new boilers, the generation of all power requirements, and the elimination of purchased power. Many of the older less efficient boilers were retired from service.

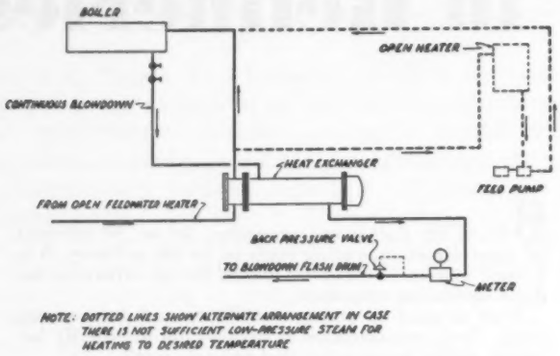

BOILER
OPEN HEATER
CONTINUOUS BLOWDOWN
HEAT EXCHANGER
FEED PUMP
FROM OPEN FEEDWATER HEATER
BACK PRESSURE VALVE
TO BLOWDOWN FLASH DRUM
METER
NOTE: DOTTED LINES SHOW ALTERNATE ARRANGEMENT IN CASE THERE IS NOT SUFFICIENT LOW-PRESSURE STEAM FOR HEATING TO DESIRED TEMPERATURE

FIGURE 1
Heat Exchange from Blowdown to Feed Water.

Attractive economies often can be made by a study of old boiler plants. The installation of blowdown exchangers, more efficient burners, more efficient maintenance of furnaces and baffles, fans, pumps, etc., and more efficient combustion controls are some of the many items which may be investigated to improve the efficiency of old existing plants.

Heat Exchange from Boiler Blowdown

Waste heat from boiler blowdown or other sources may be utilized to increase feed-water temperature by the installation of heat-exchange equipment.

The flow diagram illustrated in Figure 1 shows one arrangement of such equipment. In this instance a surplus of low-pressure steam for feed-water heating was available. After the feed water had been heated to the maximum temperature obtainable with the low-pressure steam, it was passed through the blowdown heat exchanger and additional heat was recovered—as the blowdown was at a higher heat level than the low-pressure steam available for heating. If there is a shortage of low-pressure steam, the blowdown heat exchanger could be installed in the system ahead of the low-pressure steam, as shown by dotted lines.

Boiler efficiency will be increased roughly 1 percent for each 10° F. rise in feed-water temperature on boilers operating at 150 psi pressure and no superheat.

Steam Atomizing-Oil Burners

Obsolete or "home-made" steam atomizing-oil burners often use excessive amounts of steam for atomization. Steam-consumption tests, which were made on various makes of steam atomizing-oil burners, indicate that steam required for correct atomization will vary from 1½ to 6 percent of total generation, or from 0.20 to 0.85 pound of steam per pound of oil atomized. The burners taking 1½ percent of the total generation represent the better commercial burners, and "home-made" burners account for the figure of 6 percent. The usual consumption for commercial burners, when properly adjusted and maintained, is in the range of 2.5 to 3.0 percent. Consumption may exceed this appreciably, however, if the burners are not maintained properly and if the operators do not adjust the burners for the minimum steam requirement to give proper atomization.

Usage of Utilities

After utilities have been generated as economically as possible and put into the distribution systems, we then are confronted with the problem of efficient usage. As stated previously, this is a more complicated problem than generation. A very limited personnel is involved in the generation of utilities and, with proper instrumentation of the generating plant, the operation of the generating facilities can be checked readily. Any sources of waste easily are located and corrected.

However, the process operators who are going to take their power and steam requirements from the distribution systems are concerned primarily with obtaining the maximum yield of specification products from their respective operations. In order to achieve this objective, utilities in excess of those required for the most economical operation often are used.

Familiarize Operator with Cost of Utilities

One very effective way to reduce wastes of this nature is to make the operating personnel familiar with approximate costs of the various utilities such as steam, power, water, and compressed air. An educational program can be carried out by bulletin-board posters, personal contact, or some other suitable means. The information should be presented in such a manner that pounds of steam, kilowatt hours, or gallons of water readily can be translated into dollars and cents by the operators.

Competent Supervision of Utility Distribution

Constant supervision of the distribution and usage of utilities by competent personnel, working in cooperation with the operating forces, can do much toward decreasing the consumption of utilities used for process work. The supervising personnel should be thoroughly familiar with the processes involved, and should have the confidence and full cooperation of operating departments.

Without this supervision and cooperation, we might expect to find many situations where steam, power, or water is being used in excess of economical requirements. For instance, we may find that products are being cooled to lower temperatures than are necessary, requiring more water than should be used, or that more open steam is being used in a fractionating tower than is necessary.

Assume for the moment that an excess of open steam is used in a fractionating tower: Operating in this manner will require pumping additional water to condense the excess steam, additional pumping over the cooling towers—the capacity of which already may be limited—and additional makeup water to the cooling tower. Pumping this additional water requires an increase in power consumption. The increase in power consumption, however, will not be in direct proportion to the increase in water requirements. That part of the pumping head that is due to pipe friction will vary roughly as the squares of the velocities or rates of flow through a given system.

Assuming the friction head was 50 feet and that flow was increased 10 percent, the new pumping head due to friction $\left(\frac{1.10}{1.00}\right)$ times 50 equals 60.5 feet, or an increase in friction head of 21 percent.

Thus, because steam in excess of requirements was used in a tower, it became necessary to use more water than should have been required, increasing makeup water to the cooling tower; and excess power was wasted handling the increased water requirements against higher heads than would have existed had the proper amount of steam been used.

Utilities Are Affected by Changes in Operations

All of us are familiar with the rapidity with which refinery processes change, due to the demand for new and improved products, the obsolescence of some processes, etc. These changes in operation often appreciably change utility requirements. At such times as process operations are changed, utility requirements should be checked closely to determine if existing systems economically will handle the new loads. Mechanical equipment on the process units affected should be checked to see if it is suited to the new operating conditions. By making proper modifications, much of the equipment may be adapted to the new load conditions.

It probably will be found also that, although other pieces of the available equipment could be used, it would not be economical to do so, because new equipment designed for the new operating conditions often will pay for itself in a short time, due to its higher operating efficiency.

Effect of Changing Operating Conditions on Centrifugal Pumps

As an example, a certain process as originally designed required 3375 gallons per minute of water at 100 feet pumping head. Due to the installation of heat-exchange equipment, changes in charge rate, and other operating conditions, the condensing and cooling-water requirements were reduced to 2500 gallons per minute and the pumping head to 90 feet.

Water for the unit was supplied by motor-driven centrifugal pumps. The pumps were purchased originally to supply 3375 gallons per minute with 100 feet discharge head. Motor speed was 1160 r.p.m. The impeller diameter was 16 inches.

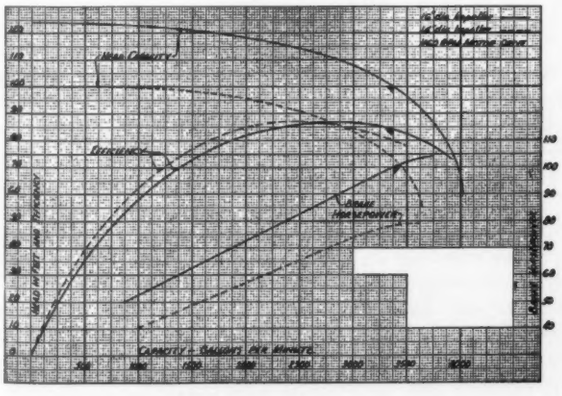


FIGURE 2
Centrifugal-Pump Characteristic Curves Showing Effect of Different Impeller Diameters.

In Figure 2 we have shown the characteristic curves for the pump with the original 16-inch diameter impellers.

After he had reviewed the new pumping conditions, the manufacturer advised that, by turning the original impeller down to 14½-inch diameter, the pump satisfactorily would meet the new conditions of 2500 gallons per minute against a discharge head of 90 feet.

The characteristic curves for the 14½-inch diameter impeller also are shown in Figure 2.

From an inspection of the curves it will be noted that we could have obtained the 2500 gallons per minute required with no changes whatever being made to the pump. However, the head, when delivering this capacity, would have been 114 feet—whereas only 90 feet was required. To pump the 2500 gallons per minute against 114-foot head would require 83 brake horsepower. Now, by changing the impeller to 14½-inch, the 2500 gallons per minute was delivered at a discharge head of 90 feet, requiring 65 brake horsepower, or a reduction of 16 horsepower. The power consumption would be reduced 21.7 percent by installation of the 14½-inch diameter impeller.

Steam-Turbine Water Rates

Steam-turbine nozzles are designed for maximum efficiency at a given steam pressure and steam flow. If original design conditions later should be changed to the extent that power requirements would be reduced appreciably, the nozzles would be working at a low efficiency, due to decrease in steam pressure in the nozzle ring or steam chest. A pressure gauge should be installed on the nozzle ring, and design steam pressure maintained as closely as possible—either by hand valves to cut out some of the nozzles, or by renozzling for the new operating load.

As an indication of the magnitude of savings that might be made in this manner, a turbine originally installed to carry a 100-horsepower load at 3600 r.p.m. with initial steam pressure of 150 psi gauge, 0° superheat, and 15 psi back pressure required a water rate of 52 psi, or a flow of 5200 pounds per hour. Due to a change in operating conditions, the load was reduced to 50 horsepower at 2850 r.p.m. Steam flow under these conditions was 3540 pounds per hour. By installing a hand valve to cut out a number of nozzles and bring steam pressure up to the design point on the remaining nozzles, the steam flow was reduced to 2960 pounds per hour, or a saving of 580 pounds per hour. This represents a saving of approximately 16 percent. At 20 cents per 1000 pounds of steam, this change would pay for itself in less than a month of continuous operation.

Scavenger Turbine Drives

Refinery steam and power balances are difficult to maintain, and at times considerably more low-pressure steam is available than is required for heating and processing. This often can be used to advantage for low-pressure condensing turbine drives. With steam at 10 psi gauge and 24-inch mercury vacuum, water rates of 30 pounds per brake horsepower easily may be obtained in turbines of approximately 200 horsepower. Water rates of 40 pounds may be had on turbines of 60 horsepower. Considering the low-pressure steam as waste, the only operating expense would be condenser water and steam for the ejector.

Before installing the scavenger turbines, however, a study should be made to determine if the supply of exhaust steam more economically might be eliminated by motorizing some steam drives or changing

some of the back-pressure steam drives to condensing operation.

Power consumption required for pumping water often may be decreased appreciably by cleaning water lines. Pressure loss due to pipe friction should be checked periodically. When this loss becomes excessive, or the required carrying capacity of the lines is affected, the lines should be cleaned. Scaled or tuberculated lines normally can be cleaned mechanically with scrapers that are forced through the lines by water pressure.

In the following tabulation are given some data on a 10-inch line before and after cleaning. It will be noted that the friction loss before cleaning was 3.4 times as much as the theoretical loss for a 10-inch line having a "C"* value of 100; after cleaning, 1.3 times as much.

	Before Cleaning	After Cleaning
Total head, feet	165	142
Gallons per minute	830	1,200
Friction head, feet per 100 ft	2.60	1.80
Theoretical friction head, feet per 100 ft	0.76	1.40

Water Booster Pumps

A survey of water requirements often will indicate where savings in power required for pumping can be reduced. A study was made of the water-supply system in one plant, and it was found that, of the 8000 gallons per minute being pumped against a discharge head of 185 feet, 6000 gallons per minute could be used at 140-foot head with some few changes. Only 2000 gallons per minute was required at 185-foot head.

Inasmuch as the water pumps were motor-driven, the impellers were turned down to deliver 8000 gallons per minute at 140-foot discharge head. A booster pump was installed to deliver 2000 gallons per minute, taking suction on the 140-foot-head line and raising the head to 185 feet.

Power saving was:

8000 gallons per minute at 185 feet and 85 percent efficiency = 440 horsepower.
8000 gallons per minute at 140 feet and 84 percent efficiency = 336 horsepower.
2000 gallons per minute at 45 feet and 82 percent efficiency = 28 horsepower.
Horsepower saving = 76.

Insulation of Lines and Equipment

To keep insulation at its peak efficiency and save the maximum quantity of heat, insulation should be inspected periodically to make certain that it is weatherproof, fits surfaces snugly, and has not lost its efficiency due to extreme temperatures or damage from leaks in the surface insulated. This is very important on lines exposed to the elements or subject to severe vibration.

Reciprocating Steam Pumps and Steam Engines

The size of steam cylinders on steam-driven equipment should be watched closely, and kept to a minimum consistent with operating conditions. Steam consumption may be two or three times that actually required, if the steam-cylinder size is greatly in excess of that required.

(Note: The items discussed hereinbefore are only a few of the many that might have been mentioned whereby economies in fuel have been effected either in the generation or usage of utilities. They are, however, representative of the various ways in which the consumption of fuels used in a refinery, outside the refinery processes proper, may be kept to a minimum.)

Hereinafter will be discussed some of the methods used to reduce fuel consumed directly in process operations.

Two-Stage Distillation on Solvent-Recovery System

Figure 3 shows simple flow diagrams of two solvent-recovery systems. The left half of the figure shows an early design utilizing single distillation under 25 inches mercury vacuum and high circulating rates through the heater.

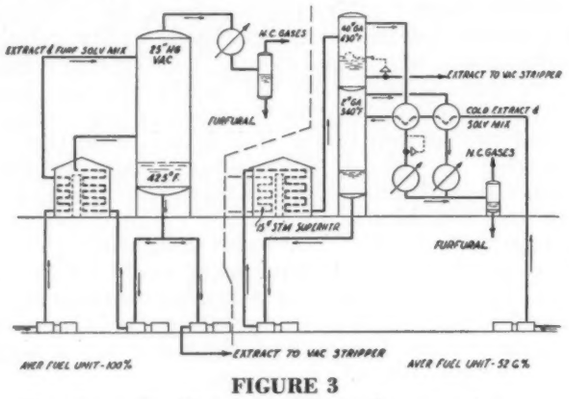


FIGURE 3
Two-Stage Distillation on Solvent-Recovery System.

The flow diagram on the right shows a later design making use of two-stage distillation. Here the incoming mix charge is exchanged first against the vapors from the atmospheric section of the tower, and then against the vapors from the 40-pound section of the tower, before going into the atmospheric section of the tower.

Approximately 40 to 45 percent of the work is done in the atmospheric section of the tower. The 40-pound section removes about 50 percent of the solvent, and 5 percent is removed in the stripper.

It will be noted that the average fuel consumption was reduced 47.3 percent on this operation, due to the use of two-stage distillation.

Heat Exchange from Hot Streams

A typical flow diagram of a crude still is shown in Figure 4. Another type of unit might have been shown, but this particular unit illustrates our point very well.

Briefly, the crude charge is passed through a series of heat exchangers in order to pick up heat in the crude charge, and at the same time cool the hot streams coming in from the tower. This has a twofold advantage: an attractive fuel saving is made, because we are recovering 46 percent of the heat input to the crude charge; and, due to the cooling of the streams by the crude charge, cooling-water requirements are decreased appreciably.

Liquid-Gas Storage

The rate of gas production in a refinery is never exactly the same as the rate of consumption; and, unless some storage or surge capacity is provided, gas will be wasted during peak production periods, and fuel from some other source must be provided

* $S = \left(\frac{V}{1.318CR^{0.63}}\right)^{1.85}$, Hazen and Williams formula for friction loss in pipe lines.

during the time that the production of fuel gas is less than the amount required for refinery operations. The excess gas can be stored either in gas or liquid form. Gasometers are used if gas is to be accumulated as such. If the gas can be accumulated in liquid form, this is usually more desirable, because much less storage space is required, and the gas can be released at sufficient pressure to go directly into the fuel mains. If stored in a gasometer, it has to be put into the fuel mains with compressors which require power or fuel consumption.

Figure 5 shows one method of liquid-gas storage for balancing gas production and consumption. The particular process is a stabilizing plant. The excess reflux is accumulated in the pressure storage tank. So long as the plant fuel gas-line pressure is above a certain pressure, liquid gas is stored. However,

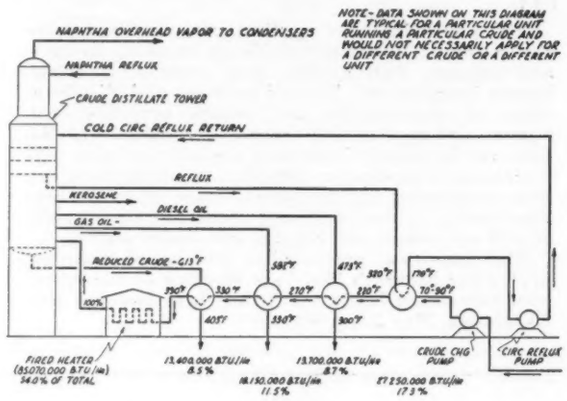

NAPHTHA OVERHEAD VAPOR TO CONDENSERS
NOTE - DATA SHOWN ON THIS DIAGRAM ARE TYPICAL FOR A PARTICULAR UNIT RUNNING A PARTICULAR CRUDE AND WOULD NOT NECESSARILY APPLY FOR A DIFFERENT CRUDE OR A DIFFERENT UNIT
NAPHTHA REFLUX
CRUDE DISTILLATE TOWER
COLD CIRC REFLUX RETURN
REFLUX
KEROSENE
DIESEL OIL
GAS OIL
REDUCED CRUDE - G15°F
FIRED HEATED (85070,000 BTU/hr) 54.0% OF TOTAL
13,400,000 BTU/hr 8.5%
18,150,000 BTU/hr 11.5%
13,700,000 BTU/hr 8.7%
27,250,000 BTU/hr 17.3%
CRUDE CHG PUMP
CIRC REFLUX PUMP

FIGURE 4
Heat Exchange from Hot Streams to Crude Charge.

as soon as the pressure drops below this set pressure, the regulating valve opens and gas is delivered to the fuel line through the heater and pressure-control valve. In this way the fuel gas-line pressure is maintained so long as liquid is available in the storage vessel.

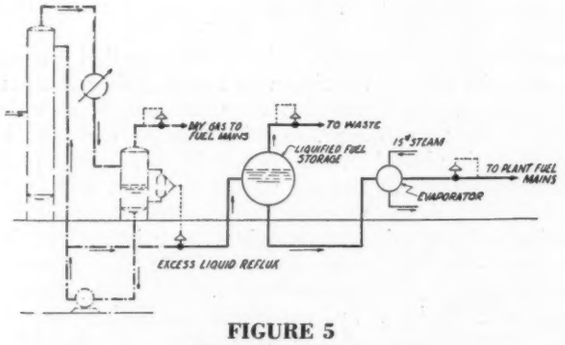


FIGURE 5
Propane Storage.

Without this storage capacity is would be necessary to waste gas at such times as gas was being produced at a higher rate than it was being consumed; and when production did not meet requirements, it would be necessary to supplement the fuel supply with fuel oil, coal, coke, or probably gas purchased from an outside source.

The capacity of the storage vessel, evaporator, and related equipment will depend, of course, upon the quantity of liquid gas available, fluctuation in production and consumption, and the duration of these periods.

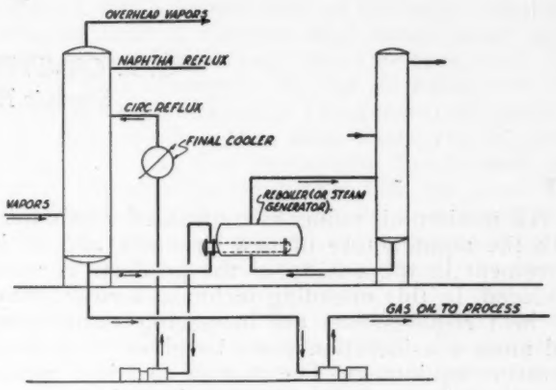


FIGURE 6
Recirculating Reflux.

With liquid storage, a vessel 5 feet in diameter and 27 feet deep will store approximately the same fuel value as a 250,000 cubic foot gasometer.

Heat Recovery from Recirculating Reflux

Fractionating towers often require large quantities of circulating reflux. The heat in this reflux must be absorbed in some medium, in order to do the required cooling in the tower. The heat could be removed by exchanging to water; but this serves no useful purpose, and would be at the expense of power expended in pumping the water required.

Figure 6 illustrates how the hot reflux is used in a reboiler—replacing steam, and thereby saving fuel at the boiler house, besides making this steam-generating capacity available for other uses. Power for pumping the required amount of water also is saved.

Hot reflux might be used also to generate steam in much the same manner, and this would reduce also the quantity of fuel required at the boiler house. There are many such installations that have been in satisfactory service for long periods of time.

Conclusion

There are, of course, many other ways in which fuel consumed by the processes might be reduced; but the examples cited serve to illustrate the possibilities that exist. A study of the various processes in use, no doubt, will present other ways in which fuel requirements may be reduced.

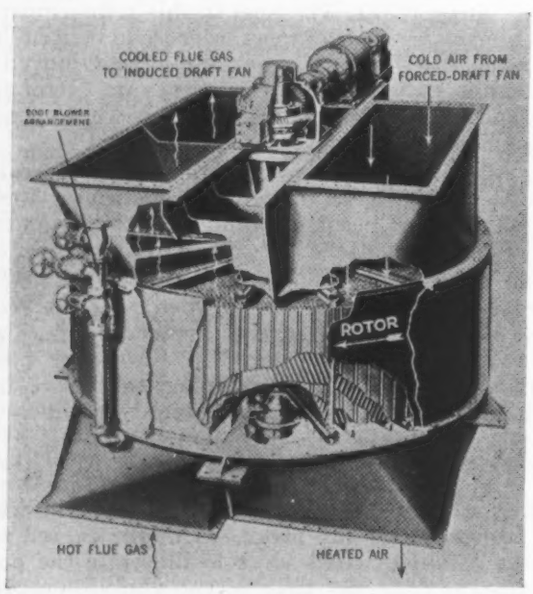
Regenerative-Type

Air Heaters for Refinery Use

O. F. CAMPBELL and T. B. KIMBALL
Sinclair Refining Company

THE modern oil refiner is confronted continuously with the manufacture of new products and an improvement in the quality of the products currently produced. In this unending technical forward march the heat requirements are increasing continuously, and more consideration must be given to heat-conservation equipment. The cost of fuel in a modern oil refinery is usually the largest single item of operating cost; and, if fuel costs are to be minimized, fuel consumption must be reduced.

There are many methods to conserve heat. The more common method of heat conservation is by the use of heat exchangers, which recover waste heat and thereby reduce the initial amount of heat required. The justification for heat-recovery equipment depends almost entirely upon fuel prices; the higher the fuel price, the greater the justification for heat-recovery equipment. When fuel has a low value, usually no economy results—except for increasing plant capacity—from the installation of heat-recovery devices. At the present time fuel prices are on the increase, and there appears a greater opportunity to install fuel-saving equipment.



Courtesy Air Preheater Corporation

FIGURE 1
Vertical-Top - Drive-Type Ljungstrom Air Heater.

The purposes of this paper are to present for the further consideration of the oil industry: 1, one type of heat exchanger—the Ljungstrom air heater; 2, application of this heat exchanger to downdraft deFlorez cracking-still furnaces; 3, economies that may be effected by its use; 4, daily operating data of this type of heat exchanger and, 5, the advantages and disadvantages of this type of heat exchanger.

THE paper includes applications of regenerative air heaters to downdraft deFlorez cracking heaters, and presents fuel savings and economics of air-heater installations. The advantages and disadvantages of regenerative air heaters are discussed. Operating data covering several commercial installations are included. Comments are included also with reference to air-heater corrosion, fouling, cleaning, heat absorption by oil tubes, more efficient heat distribution by use of forced preheated air, smoother still operation, and repairs and maintenance.

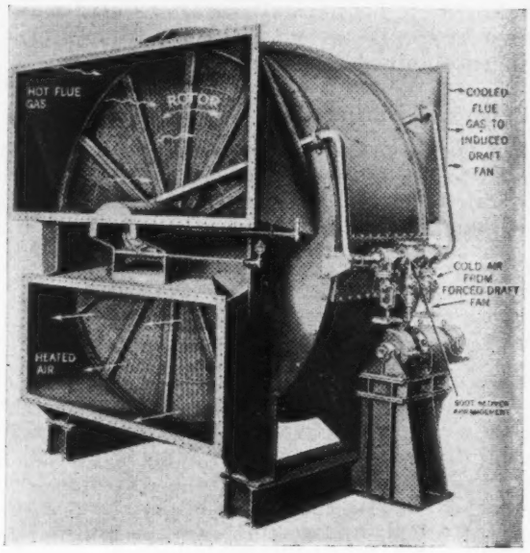
This paper was presented to Division of Refining, before the Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

Description

The Ljungstrom air heater, as shown in Figures 1, 2, and 3, operates on the continuous-counterflow-regenerative principle. As may be seen from the illustrations, the construction by which this continuous-counterflow-regenerative principle is applied includes the use of a slowly moving rotor containing the heating surface. Each revolution produces a complete cycle of heat exchange, in which heat from the hot flue gases is absorbed constantly by the metal plates and is given up to the air as the rotation moves the heated plates into the path of the combustion air. The housing of the Ljungstrom air heater is divided into two end compartments and a middle compartment, the latter containing the rotor. The end compartments are divided by partitions, confining the flue gases to one side of the apparatus and the air to the other. Seals are used to keep to a minimum the leakage of air into the flue gases. Different types of seals are used, such as the bulb-type and the labyrinth-type, and the use of each is governed by the operating temperature of the air heater. There are two general designs of Ljungstrom air heaters—the vertical and the horizontal. Each type operates with equal satisfaction, and the type selected depends upon the convenience of the installation.

Ljungstrom air heaters are built in a number of standard sizes in a sufficient number of steps between the largest and the smallest to be adapted easily to units of any capacity. They also are built for any entering flue-gas temperature range up to approxi-

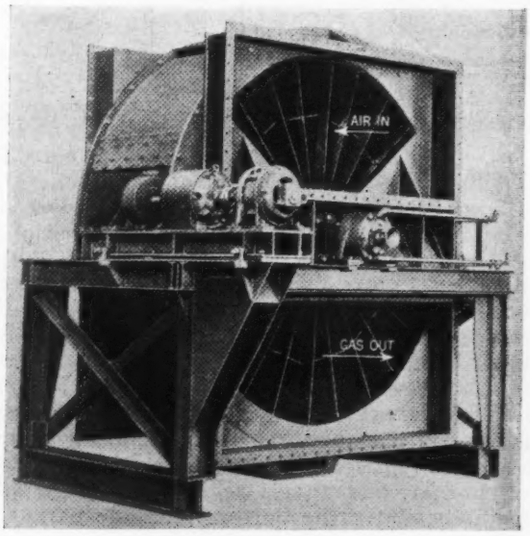
mately 2,000° F. For the higher temperature ranges, from 1,000 to 2,000° F., suitable alloys are used to withstand the higher temperatures. For the higher temperatures, alloy labyrinth seals usually are used; and, for the lower-temperature operations, the bulb- or expansion-type seals normally are employed.



Courtesy Air Preheater Corporation

FIGURE 2
Horizontal-Type Ljungstrom Air Heater, Showing Soot Blowers and Flue-Gas Flow Through Upper Section.

The economical design and operation of a cracking-still furnace, equipped with expensive alloy tubes and headers, demands that the Btu absorption per square foot of oil-heating surface per hour be maintained



Courtesy Air Preheater Corporation

FIGURE 3
Horizontal-Type Ljungstrom Air Heater, Showing Air Flow Through Upper Section, Water-Cooled Center Shaft, and Driving Mechanism.

as high as possible in order to reduce the number of tubes and headers and to reduce pumping costs. It is conceded generally that, in the modern cracking-still furnace, the oil tubes located in the radiant section of the furnace absorb more heat per square foot of surface per hour than does the convection bank of tubes; and, therefore, it appears evident, from a maximum heat-absorption standpoint, using a minimum amount of surface, that all of the oil tubes should be located in the radiant section. To do this without adding additional heat-recovery equipment would result in a very inefficient furnace.

The deFlorez downdraft furnace without a convection bank, but equipped with an air heater capable of operating with a flue-gas inlet temperature under 1,400° F., provides a unit that can operate at high rates of heat absorption by the oil tubes, and also operate at a high efficiency. The general arrangement of the furnace, air heater, fans, ducts, etc., is shown in Figure 4. The flue gases from the furnace pass directly through the air heater into the suction of the induced-draft fan, and then to a self-supporting steel stack. The air for combustion passes from the discharge of the forced-draft fan directly to the air heater, and then to the burners. The forced- and induced-draft fans are driven by a single motor, which is interlocked electrically with the air-heater driving motor so that, when the rotor stops, the fan motor stops. This electrical interlocking device protects both air heater and fans. Located between the forced-draft fan and the induced-draft fan is a hydraulic coupling. By varying the oil level in the hydraulic

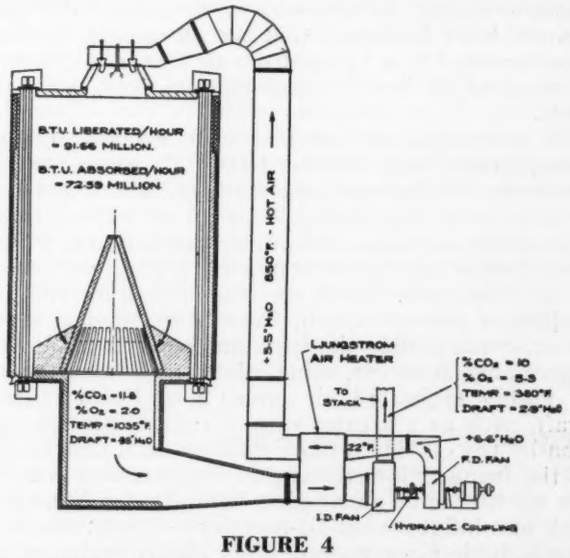


FIGURE 4
Downdraft deFlorez Furnace Equipped with Ljungstrom Air Heater.

coupling the speed of the induced-draft fan can be controlled as desired to provide the necessary draft on the outlet of the air heater, with minimum power requirements.

Economy of Installation

The economy of eliminating the convection bank of a cracking-still furnace and substituting for it an air heater depends upon the cost of the convection bank, the cost of air heater and fans, the cost of power to drive the fans, and fuel price. Table 1 is included to show the expected performance of a cracking-still furnace that is equipped with a convection bank and a cracking-still furnace, wherein the convection bank has been eliminated and an air heater substituted for it. For comparative purposes, the temperature of the charging stock to the furnace has been assumed to be 700° F; fuel price is assumed to be equivalent to $1.00 per barrel of fuel oil, and

TABLE 1
Comparative Fuel and Power Costs

	With Air Heater	Without Air Heater
1. Heat absorption per hour, millions of Btu	70	70
2. Oil-inlet temperature, °F	700	700
3. Flue-gas temperature to stack, °F	400	950
4. Carbon dioxide to stack, percent	10.0	11.0
5. Oxygen to stack, percent	5.2	3.7
6. Efficiency (assuming 5 percent radiation loss), percent	78.5	66.0
7. Millions of Btu required per hour	89.17	106.06
8. Annual cost of fuel ($1.00 per barrel of fuel oil —8,000 hours)	$109,760	$130,560
9. Kilowatt-hours	80	.....
10. Annual cost of energy at 7 mills per kilowatt-hour (8,000 hours)	$ 4,480	.....
11. Annual operating cost—fuel and energy (8,000 hours)	$114,240	$130,560
12. Annual fuel saving	$ 20,800	.....
13. Annual net saving in operating costs (fuel saving less energy costs)	$ 16,320	.....

the cost of electrical energy at 7 mills per kilowatt-hour. The heat absorbed by the oil tubes has been assumed to be 70 millions of Btu per hour for each furnace. From the annual fuel saving has been deducted the cost of electrical energy for driving the forced- and induced-draft fans. The annual net saving under the above conditions, which amounts to $16,320, more than justifies the added cost, if any, of an air heater and fans over the conventional cracking still equipped with a convection bank. Estimates covering installations of downdraft deFlorez heaters have indicated that an all-radiant furnace, supplemented by a Ljungstrom air heater, is the more economical in both capital charges and operating costs.

In a conventional cracking still, wherein flue-gas temperatures may exceed 1,400° F. when the gas leaves the radiant section, the installation of a convection bank, supplemented by an air heater, might prove more economical than the installation of a high-temperature air heater requiring high-priced alloys in its fabricaton. There are many cracking stills installed at present which, from a fuel-saving standpoint, could justify the installation of an air heater. There are, moreover, other advantages from the use of highly preheated air under forced and induced draft, such as a greater rate of radiant-heat absorption by the oil tubes, more uniform heat distribution in the furnace, lower flue-gas temperatures entering the air heater or convection bank, better flame control, less influence on oil-transfer temperatures from atmospheric changes, etc. Also, highly preheated air improves the burning of liquid fuel, especially when heavy residual tars or asphalt is burned.

Normal Operating Data

Tables 2 and 3 present some normal operating data of two groups of deFlorez furnaces, without convection banks, that are equipped with Ljungstrom air heaters. The furnaces in group I are approximately half the size of the furnaces in group II. Tables 2 and 3 include different sizes of air heaters with different lengths of air-heater elements. Variable firing rates for the two groups of furnaces are included in order to show air-heater performance over a wide range of operating conditions. The firing rate of one of the smaller furnaces, for example, is shown to be higher than some of the firing rates of the larger furnaces. The variations in air and flue-gas temperatures are a function of the ratio of air to flue-gas flow through the air heater. If the cold air that infiltrates into the furnace enters into combustion, the flue-gas temperature entering the air heater rises—and so does the hot air as well as the stack temperature. Infiltration of cold air into the furnace should be avoided to obtain maximum efficiency. It is noted that the average efficiences of these furnaces equipped with air heaters, regardless of firing rates, are higher than most refinery boilers. All efficiencies are calculated on the gross heating value of the fuel. Data shown are for normal operations, and were not taken under special test conditions. Better efficiencies have been obtained under tests.

Special Burner Used on Latest Design

When highly preheated air is used, attention must be given to the burner design and material in order to provide burners that will operate satisfactorily and withstand high air temperatures without undue

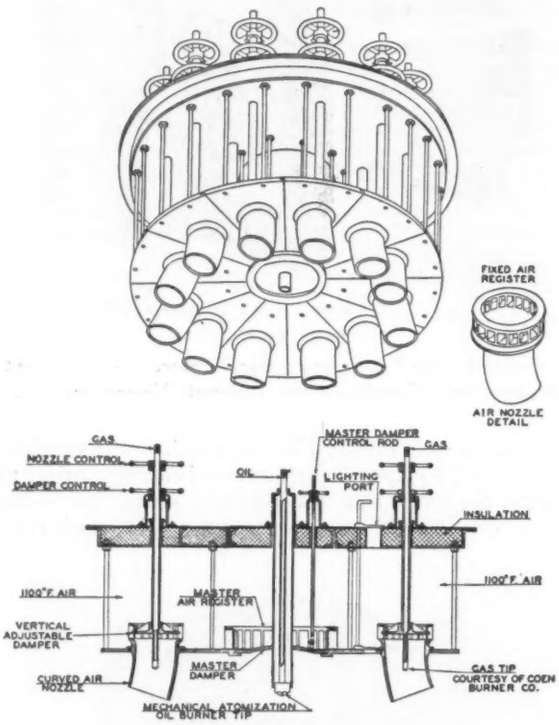


FIGURE 5
Special Burner used with Downdraft deFlorez Furnaces and Ljungstrom Air Heaters.

maintenance. Figure 5 shows the design of the special burners that have been used in recent installations of downdraft deFlorez furnaces equipped with Ljungstrom air heaters. The description of design and operation of this special burner is given in the July, 1938 issue of the REFINER & NATURAL GASOLINE MANUFACTURER—except that the three steam atomizing-oil burners have been replaced with one 6-tip mechanical atomizing-oil burner, and an air register has been added immediately above the bottom manhole damper.

Disadvantages of Ljungstrom Air-Heater Installations

The installation of any piece of equipment always has its advantages and disadvantages; the latter forthwith are presented for consideration. The disadvantages of a Ljungstrom air heater are, primarily, the high power requirements for the forced- and induced-draft fans and air leakage. In some installations the forced- or induced-draft fans may be eliminated, but normally this is not the case. The power requirements

TABLE 2
Operating Data—deFlorez Furnaces

	GROUP I						
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
1. Fuel used	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas
2. Carbon dioxide entering air heater, percent	10.6	10.4	11.0	10.4	10.0	12.0	11.4
3. Oxygen entering air heater, percent	4.3	4.6	3.7	4.8	5.4	2.0	3.1
4. Carbon dioxide leaving air heater, percent	9.6	9.0	8.8	9.0	9.3	10.0	9.6
5. Oxygen leaving air heater, percent	6.0	6.9	7.3	6.8	6.8	5.3	5.8
6. Flue-gas temperature into air heater, °F	1,195	1,200	1,195	1,117	1,230	1,210	1,190
7. Flue-gas temperature out of air heater, °F	500	450	495	521	630	440	465
8. Air temperature into air heater, °F	26	22	31	80	8	33	33
9. Air temperature out of air heater, °F	860	810	885	796	1,010	830	835
10. Air pressure into air heater, inches of water	4.95	4.90	6.4	5.0	5.1	6.75	7.75
11. Air pressure out of air heater, inches of water	3.45	3.50	5.0	3.0	4.5	5.50	5.50
12. Flue-gas draft into air heater, inches of water	0.85	0.85	0.90	0.80	1.53	0.75	0.88
13. Flue-gas draft out of air heater, inches of water	1.90	1.60	3.20	2.20	4.46	1.88	2.50
14. Air-heater leakage,* percent	10.5	15.6	25.0	15.5	7.5	20.0	17.7
15. Stack loss, percent	20.0	19.2	20.0	19.5	22.5	17.5	18.0
16. Efficiency,† percent	75.0	75.8	75.0	75.5	72.5	77.5	77.0
17. Millions of Btu liberated in furnace	47.3	49.5	50.8	52.1	57.7	58.0	70.0
18. Millions of Btu absorbed by oil tubes	35.47	37.52	38.1	39.33	41.8	44.95	53.9
19. Length of elements, inches	27	27	27	27	27	27	27

* Percent leakage = $\frac{\text{(percent carbon dioxide in)—(percent carbon dioxide out)}}{\text{(percent carbon dioxide out)}} 100.$

† Percent efficiency =[100 percent—(stack loss+5 percent radiation loss)].

for the forced- and induced-draft fans, according to average tests over extended periods of time, with fans designed to deliver air at a static pressure of 9 inches of water and a suction pressure on the induced-draft fan of —5 inches of water, amounts to approximately 0.9 kwh per million Btu liberated in the furnace. With air heaters having less resistance to the air and flue gas, and with less air pressure required at the burners, the power requirements necessarily will be lower. Future designs probably will modify present requirements.

The problem of air leakage is always present with this type of preheater, which depends upon some sealing device to prevent the air from leaking into the flue gases. The amount of leakage depends primarily upon the difference in pressure between the air and the flue gas, and upon the effectiveness of the seals. For high-temperature air heaters, in which expansion is greatest, the average leakage approximates 15 to 20 percent. The amount of leakage of air into the flue gases does not affect materially the efficiency of the heat recovery of the preheater, as most of the leakage occurs at the cold end of the air heater. In actual practice the principal effect that leakage has is an increase in power requirements for both the forced- and induced-draft fans.

Another disadvantage of the Ljungstrom-type preheater is that the seals wear out and must be replaced from time to time. Also, as the seals gradually wear they must be readjusted in order to keep the leakage to a reasonable amount. The cost of replacing and adjusting seals is, however, not great, as the seals usually last from two to five years, depending upon the service, and adjustments are made approximately twice each year. The adjustment of seals, or replacement of the seals, can be made readily during any normal shutdown.

Care must be taken also to avoid excessive accumulations of soot or sulfur deposits, which are liable to auto-ignition in case rotor stoppage occurs from power failure or from mechanical difficulty. In one instance when this actually occured, the air-heater elements were melted partly when the operator failed to use smothering steam. The units, however, continued in operation for approximately 30 days after resumption of power before they were repaired on a scheduled shutdown. Efficiency remained substantially normal; however, firing conditions were disturbed somewhat by surging of air static and flue-gas draft.

Advantages of Ljungstrom Air-Heater Installations

The advantages of the Ljungstrom air heater are many and varied. For equivalent heat recovery the Ljungstrom air heaters are smaller, more compact, and weigh less than other types of air heaters. Foun-

TABLE 3
Operating Data—deFlorez Furnaces

	GROUP II						
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
1. Fuel used	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas	Refinery gas
2. Carbon dioxide entering air heater, percent	10.7	10.2	11.4	11.8	11.0	10.8	11.8
3. Oxygen entering air heater, percent	3.2	4.1	3.2	1.8	3.4	3.8	2.0
4. Carbon dioxide leaving air heater, percent	9.1	8.8	9.2	9.8	8.7	9.0	10.0
5. Oxygen leaving air heater, percent	5.9	6.4	5.9	5.8	7.4	6.9	5.3
6. Flue-gas temperature into air heater, °F	1,010	990	980	960	1,025	980	1,035
7. Flue-gas temperature out of air heater, °F	470	465	365	355	405	390	380
8. Air temperature into air heater, °F	60	60	26	62	56	10	22
9. Air temperature out of air heater, °F	730	705	715	780	855	815	850
10. Air pressure into air heater, inches of water	4.2	3.8	4.4	5.0	6.25	5.5	6.6
11. Air pressure out of air heater, inches of water	2.6	2.4	3.0	4.0	4.75	4.25	5.5
12. Flue-gas draft into air heater, inches of water	0.75	0.68	0.80	0.90	1.10	0.80	0.95
13. Flue-gas draft out of air heater, inches of water	2.5	2.3	2.2	2.0	2.2	2.4	2.9
14. Air-heater leakage,* percent	18.0	16.0	23.9	20.0	26.4	20.0	18.0
15. Stack loss, percent	19.8	19.9	16.1	15.5	17.8	16.5	15.8
16. Efficiency,† percent	75.2	75.1	78.9	79.5	77.2	78.1	79.2
17. Millions of Btu liberated in furnace	56.3	59.4	71.68	73.6	84.7	89.95	91.66
18. Millions of Btu absorbed by oil tubes	42.34	44.61	56.55	58.51	65.39	70.25	72.59
19. Length of elments, inches	27	27	36	48	48	48	48

* Percent leakage = $\frac{\text{(percent carbon dioxide in)—(percent carbon dioxide out)}}{\text{(percent carbon dioxide out)}} 100.$

† Percent efficiency =[100 percent—(stack loss+5 percent radiation loss)].

dations and installation costs are low. Ljungstrom air heaters are more efficient than the envelope- or tubular-type air heater. They are cleaned readily, as the elements are short. During operation they are cleaned easily and effectively by steam or air soot blowers, which are operated only a few minutes each day. The elements usually are cleaned at the end of each run by washing with warm water, or they may be washed with water during normal operation if provisions have been made to dispose of the wash water. When the heating surface is washed with water, the elements are washed until the wash water no longer shows acidity. In the event of a fire due to an oil-tube failure, the air heater can be protected effectively by the use of smothering steam. No air heater has been lost to date due to an oil-tube failure.

The corrosion of air heaters has been one of the major reasons why these heaters have not been used more extensively in the oil industry. It is recognized generally that the cause of corrosion is due to the lowering of the temperature of the flue gases below the dew point of the acid constituents of the flue gases, and the condensed acid attacks the metal of the air heater.

The design of air heaters other than Ljungstrom air heaters usually produces localized cold spots, or dead flue-gas areas, where the flue gases are cooled below the dew point—which starts corrosion in local areas. This localized corrosion causes leakage, and the life of the air heater thereafter is very short.

In the Ljungstrom air heater each portion of the heating surface passes through the entire gas and air streams. Thus cold spots are eliminated, and the resulting temperature in the coolest region, viz., where the air enters and the flue gas leaves, is uniform in all heating plates, and is a true average of the final gas and air temperatures. The flue gases, therefore, may be reduced to appreciably lower temperatures, and higher overall efficiencies can be maintained without the danger of corrosion.

The same action by which soot accumulation is retarded tends to delay corrosion in the Ljungstrom air heater. If, at the lower loads, some condensation does form on the cold ends of the heating elements while they are in contact with the flue gases, the moisture in all but the most extreme cases is evaporated completely when clean dry air passes through the same channels. Corrosion does not necessarily increases the leakage in the Ljungstrom air heater, because the material used in the seals usually is not affected.

When and as severe corrosive flue gases are encountered, the length of elements may be reduced, or the elements may be allowed to corrode away to the extent that the exit flue-gas temperatures are higher than the dew point of the flue gases. The air heater is, therefore, self-adjusting for corrosion. Several air heaters have been in operation for approximately 3 years on downdraft deFlorez heaters, burning refinery gas containing 2,000 to 3,000 grains of hydrogen sulfide per 100 cubic feet, without excessive repairs. If it is desired to obtain maximum heat recovery under more severe corrosive conditions, special corrosive-resisting materials may be used at the point of maximum corrosion. There are other means of controlling corrosion, such as by-passing some of the cold air around the air heater, or returning some hot air to the suction of the forced-draft fan.

The high gas velocity through the short, straight gas passages greatly reduces the possibility that soot can collect on the heating surfaces. Most of the particles that may have collected are swept off by the vigorous reverse flow of clean air as the rotor turns through the air side of the air heater. No dead pockets, in which soot can accumulate, exist in any part of the heating surface, as the alternate flow of gas and air is uniform through every passage in the entire rotor. Through the action of the regenerative principle, soot and fly-ash do not retard heat transmission as in other types of air heaters, because the heat is not required to pass through the metal. The soot, as well as the metal, acts as a heat-storage and -transfer medium. The main effect that deposits have is to increase the air and flue-gas resistance, but heat recovery remains substantially the same. When clean fuel gas is used, which contains no sulfur, the air heater may be operated without cleaning.

The Ljungstrom air heater has another advantage during shutdowns. The furnace may be cooled off more rapidly by stopping the air-heater rotor and operating the forced- and induced-draft fans. To do this the electrical interlocking device between the rotor motor and fan motor is not used.

Conclusion

In conclusion, the authors feel that a Ljungstrom air heater is a dependable and economical heat exchanger, readily adapted to most oil-refinery heat-recovery programs. In many instances the air heater not only saves fuel, but also assists in the improvement of overall furnace operation, heat distribution, and an increase in furnace capacity.

Acknowledgment

Acknowledgment is hereby given to Air Preheater Corporation, Richfield Oil Corporation, and Coen Company for their assistance in furnishing the illustrations and part of the operating data.

Water-Side Corrosion

of Refinery Condensing Equipment

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WATER-SIDE corrosion represents the much-studied electrolytic type of corrosion that is affected prominently by aeration, temperature, and velocity. In this paper, electrolytic corrosion is discussed briefly, followed by a description of the corrosion that has been noted in the case of condensing equipment of cast iron, admiralty metal, copper-nickel alloys, and monel.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

THE corrosion studied in the preparation of this paper is confined to the surfaces exposed to the cooling waters. This corrosion may be viewed as a fundamental type, whose progress may be directed and controlled by the three important variables:

1. Aeration.
2. Temperature.
3. Velocity.

In order to arrive at the mechanism of the destruction of the parts studied, a brief resume of some theories and principles of corrosion will be offered.

Corrosion (General)

Corrosion that takes place in the presence of water, suitably contaminated to be a conductor of electricity, often is referred to as "electrolytic corrosion." This is the type under discussion herein.

In the presence of the electrolyte mentioned, a metal tends to go into solution, acquire a charge, and become ionized. The ions of the solution will give up positive charges to provide for the charge of the new metal ion. As an example, an iron nail placed in a copper-sulfate solution loses part of the iron to the solution. Copper, due to a loss of charge, will plate out in the form of metallic copper without a charge.

Metals often corrode, i.e., go into solution, in a liquid that does not contain a replaceable metal. In this case it is the hydrogen ions, obtained by the dissociation of water, or acid, that plate out.

The exchange of charges between metals and metallic ions is by no means haphazard, because there is a preferred direction of exchange which is sufficiently well established to permit arranging the metallic elements in an electromotive series (Table 1).

Generally speaking, any material in the electromotive series of Table 1 will go into solution and acquire a charge from any other metal lower in the series and already in solution; e.g., all metals above copper will tend to disssolve into solutions containing copper, and metallic copper will plate out of the solution. Similarly, all metals above hydrogen will tend to dissolve and to plate out hydrogen from the solution.

The other solutions, containing more or less dissolved metal, the relative positions may change. For example metals below hydrogen sometimes are able to displace hydrogen from solution. In this case the concentration of metal ions is low, and the concentration of hydrogen ions is high.

In electrolytic corrosion, one can divide the total reaction into two parts: viz., the anodic reaction, wherein the metal being corroded (i.e., going into solution) acquires its charge and becomes ionized; and the cathodic reaction, wherein the ions of some other metal or of hydrogen plate out.

The division of a corrosion reaction can be shown plainly by an experiment involving an agar solution and two indicators, potassium ferriccyanide and phenolphthalein; a corroding reagent, as sodium chloride; and a piece of metal, as a steel nail, that can be attacked. The presence of iron ions at the anodes is shown by a blue color of the ferriccyanide. The presence of hydroxyl ions at the cathodes is shown by the red color due to the phenolphthalein indicator.

The presence of dissimilar metals in contact in the presence of an electrolyte sets up a type of corrosion referred to as "galvanic corrosion." The outstanding feature of galvanic corrosion is that the differences in solution pressure, or potentials, of the two metals in a couple give rise to an electromotive force that increases the driving force behind the corrosion of the less-noble metal of the couple. It will be seen that in such a couple one metal will corrode above its normal rate in the solution, while the other metal is protected and corrodes at a less than normal rate. The importance of insulating test specimens from equipment parts can be understood in the light of the above.

The importance of relative areas of anode and cathode is sometimes overlooked in considering galvanic corrosion. In a test involving iron and copper specimens, the iron was held to a constant area, while the area of the copper varied widely. The results showed that the galvanic effect increased almost directly with the area of the cathode (copper). It was noted that the potential between the iron and copper remained constant. However, the effect was by no means constant, thus indicating the folly of depending upon potential measurements as an indication of possible galvanic effects. It further demonstrates the necessity of considering the relative areas of the two metals when the probable danger of galvanic corrosion is being estimated. As

TABLE 1
Galvanic Series for Sea Water

Anodic (corroded) end
Magnesium
Magnesium alloys
Zinc
Galvanized steel, or galvanized wrought iron
Aluminum 52SH
Aluminum 4S
Aluminum 3S
Aluminum 2S
Aluminum 53S-T
Alclad
Cadium
Aluminum A17S-T
Aluminum 17-ST
Aluminum 24S-T
Mild steel
Wrought iron
Cast iron
Ni-resist
13-percent-chromium stainless steel, type 410 (active)
50-50 lead-tin solder
18-8 stainless steel, type 304 (active)
18-8-3 stainless steel, type 316 (active)
Lead
Tin
Muntz metal
Manganese bronze
Naval brass
Nickel (active)
Inconel (active)
Yellow brass
Aluminum bronze
Admiralty brass
Red brass
Copper
Silicon bronze
Ambrac
70-30 copper-nickel
Composition G bronze
Composition M bronze
Nickel (passive)
Inconel (passive)
18-8 stainless steel, type 304 (passive)
Monel*
18-8-3 stainless steel, type 316 (passive)
Cathodic (protected) end

* Registered trade name.

an example of the effects of area: It would be more dangerous to place a steel rivet in a copper plate than to place a copper rivet in a steel plate, wherein galvanic corrosion could occur. In the latter case, the relatively large area of the plate would render negligible the increased corrosion due to the presence of the copper rivet, provided an electrolyte as good as sea water is present.

Concentration cells are an important factor in corrosion, although probably they have not received the attention deserved. Concentration cells can occur when there are differences in composition of solution in contact with a single metal at different points. When the difference in composition of the solution is due to variations in concentration of dissolved metal ions, the cells are referred to as "metal-ion cells" (Figure 1). When it is due to variations in concentrations of dissolved oxygen, the cells are referred to as "oxygen-concentration cells." The ion-concentration cell can be explained on the basis of the tendency to establish equilibrium within the cell, as metal ions enter the region of low-metal ion concentration in order to bring up the concentration to a uniform level. In the oxygen-concentration cell, the oxygen tends to be used up in the concentrated areas in an effort to come to an equilibrium. As the oxygen may be used in reactions with hydrogen at the cathodes, the region of high-oxygen concentration consequently becomes cathodic to the region of low-oxygen concentration.

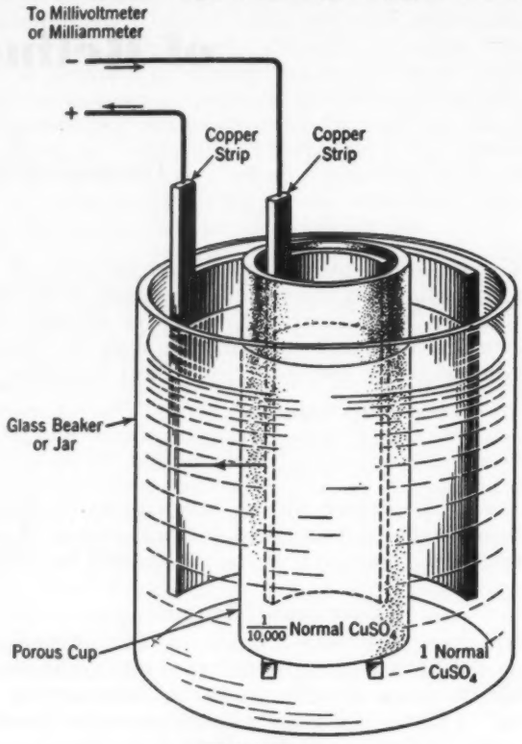

FIGURE 1
Diagram of Metal-Ion-Concentration Cell.

The potent effect of ion cells must be considered in design, especially when copper and high-copper alloys are used. Cracks or crevices should be avoided. Velocity of the flow of the attacking reagent can set up these cells by removal of ions from a given location.

In dealing with corrosion, one observes that the initial rapid rate of attack drops off in many cases, and often the attack ceases or proceeds at a negligible rate after the first violent attack.

It has been noted that the products of corrosion tend to block and stop the reaction. For corrosion (of the type under discussion) to proceed, it is important that the hydrogen be removed from the cathode surface. Otherwise, hydrogen can block the corrosion reaction. The hydrogen can be removed in two ways. It can be removed by reaction with oxygen to form water. It also can be removed by formation of hydrogen molecules that escape as a gas from the solution.

The formation of hydrogen gas does not proceed smoothly, even when the theoretical driving potential is present. In such a case, a greater potential is required, and the extra potential required for the evolution of hydrogen is called "over-voltage." The over-voltage required varies with different metals as well as with the conditions of their surfaces.

It should be noted that an evolution of hydrogen gas only occurs during corrosion when there is a concentration of hydrogen ions, as in the case of a highly ionized acid which is reacting, or when a large driving force or potential is acting. In the case

of sodium chloride, previously considered in the example of idealized corrosion, there would be an evolution of hydrogen at a slow rate.

Consideration hereinbefore has been given mainly to cathode areas. The anode area merits equal consideration, for often control of this area can control the amount of corrosion. Consider a monel bolt in a steel disc operating in sea water. By suitable painting of the monel, the accelerating effect upon the corrosion due to the coupling of dissimilar metals can be controlled. In fact, it often is advisable to coat the more-noble metal in the couple in order to minimize corrosion. It is important to note that the tendency for a metal to corrode often is controlled by the rate at which the material deposited at the anode is removed. An example is lead, because the formation of insoluble lead sulfate on the metal retards corrosion and renders lead a useful material for contact with sulfuric acid.

In continuation of the above, it should be pointed out that aluminum and high-chromium alloys are rendered resistant to corrosion by a number of reagents if first treated with an intensely oxidizing acid or solution. The corrosion products—oxide films—usually have a lower solution pressure than the metals from which they are formed, and consequently *while intact* confer upon the metal an artificial degree of "nobility"—often referred to as "passivity." In general, the higher a metal exists in the electromotive series (Table 1), the more readily it tends to become passive by development of an oxide film.

The metals and alloys relying upon an oxide film for protection are perilously vulnerable to any break in the film, because a large potential can exist, between the oxide film and the metal, that is unfavorable to the metal. The result of such breaks in the film may be local fissures and pits. The presence of extraneous material, products of corrosion, or a deficiency of oxidizing reagents to make up the oxygen removed by the hydrogen ions, all can allow the difference in potential between film and metal to be effective in the destruction of the metal.

Another factor tending to retard corrosion is that the discharge of hydrogen at the cathode areas brings about a depletion of the hydrogen ions. This in turn results in the solution at the cathode areas becoming more alkaline, due to concentration of hydroxyl ions. Frequently the effect of alkalinity is to result in the precipitation of insoluble, protective corrosion products, as in the case of iron. In fact, it has been suggested that the distribution of the alkaline films at the cathode is more important than the distribution of oxygen in determining the areas that will be protected or corroded.

Having considered so far the theories concerning the mechanism of corrosion, attention now will be turned to specific cases of corrosion of condensing equipment by the cooling waters.

Corrosion of Condensing Equipment

Marked corrosion by cooling waters has come to the attention of the writer in the following locations:

The East Coast of the United States.
The Gulf Coast and its environs.
The West Coast.
Certain areas of the Mid-Continent.

The most vigorous corrosion, as might be expected, is associated with brackish coastal waters.

Some materials from which condensing equipment is formed are:

Cast irons.
Admiralty metal.
Copper-nickel alloys.
Monel (67 percent nickel, 30 percent copper).

The general forms of this equipment are: Pipes, special sections, and tubes. Associated with these parts are headers, tube sheets, shells, channels, covers, etc.

Cast Irons

Cast iron long has been used as the material for condensers.

The chief merit dictating the use of cast iron is the graphitic form the corrosion of this material takes. In this type of corrosion much of the ferrite of the iron is removed from the affected zone, leaving behind a black porous structure which may retain the form of the original metal, but which is devoid of its strength. The porous residual material

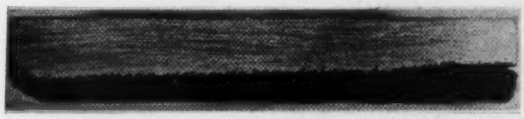

FIGURE 2
Cast Iron with Layer of Graphite Present After Corrosion.

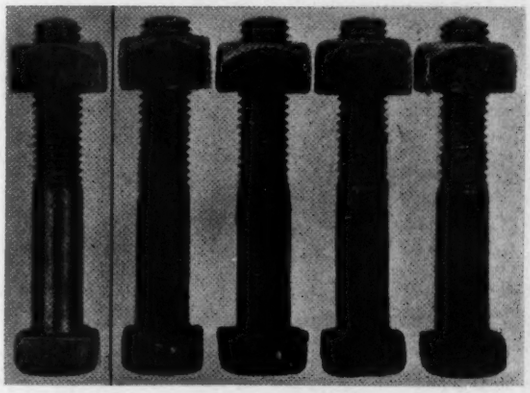

FIGURE 3
Monel Bolts, exposed 22 years in a condenser box to contaminated salt water of the Kill van Kull.

is rich in graphite and carbides, and usually contains a considerable amount of free iron[1] (Figure 2).

The layer of graphitized material may decrease or prevent further corrosion of the cast iron. This occurs when the graphitic coating reaches some depth and the pores are clogged with insoluble matter. Under these conditions cast-iron parts may outlast steel parts for a long time. The protection cast-iron parts obtain from the graphitized layers accounts for the popularity of this material and its wide usage. It is not uncommon in refineries to find cast-iron parts, after years of service, that appear sound; yet actually the parts can be cut through with a pocket knife.

Whereas the graphitic layer on cast iron often acts as a deterrent to corrosion, it must be recognized also that this layer is quite noble compared with metallic cast iron and, therefore, can accelerate the normal corrosion rate of the iron.

Table 2 should be studied in connection with the

foregoing. From (1) of this table, it is evident that the corrosion rate of iron with a graphitic coating is less than (2), an iron freshly machined; (3), (4),

FIGURE 4
Showing Plug-Type Dezincification (Magnification 3×).

and (5) indicate the accelerating effect of coupling cast iron free from a graphite layer with iron containing such a layer. It is reasonable to assume that following (5) a layer eventually will build that will reduce the corrosion rate to that obtained in (1),

TABLE 2
Results of Tests of the Effects of a Graphitic Layer Upon the Corrosion Rate of Cast Iron

	Milligrams per Square Decimeter per Day
1. Normal corrosion rate of graphite-coated cast iron	74
2. Normal corrosion rate of freshly machined cast iron	167
3. Corrosion rate of freshly machined cast iron in contact with equal area of graphite-coated cast iron (average over 9-day tests)	535
4. Initial galvanic corrosion rate	6,900
5. Final galvanic corrosion rate	372

the normal rate for the iron with a graphitic layer.

The ability of cast iron to receive and give protection against corrosion is demonstrated in the case of monel bolts (Figure 3), which served 22 years in a box-type condenser using salt water. The bolts received galvanic protection from the iron. The extension area of the iron served to dissipate the accelerating effect the bolts would have had on the corrosion of the iron.

Two methods of combating corrosion of cast iron appear available by the use of alloying agents. Small additions of nickel and nickel with chromium have served to reduce corrosion rates of cast iron by such physical means as refining the grain, reducing the graphite particle size, and limiting porosity. Large additions of alloys, such as used in Ni-resist* (approximately 15 percent nickel, 6 percent copper, 2 percent chromium), confer upon the alloy a degree of "nobility" that permits a high degree of corrosion resistance *per se*. Tests made in sea water indicate a corrosion rate for Ni-resist of one half to one fifth of that obtained for gray cast iron. In Mid-Continent water a rate of one fifth of the rate for gray cast iron was obtained for Ni-resist in comparative tests.

Whereas Ni-resist develops graphitic coatings, as does unalloyed cast iron, it is interesting to note from some tests reported:[1]

> "The results indicate that the galvanic corrosion of clean Ni-resist coupled with graphite-coated Ni-resist is small as compared with the galvanic corrosion of cast iron under similar conditions."

This is an important factor when the conditions of the layer are such as to tend towards enhancement of the corrosion rates by autogenous galvanic means.

Admiralty Metal

A very large tonnage of admiralty metal goes into the condensing equipment of refineries. This alloy has performed, in general, in a most creditable manner, and promises to hold its position for some time to come, especially in view of the results obtained from the use of inhibitors in the alloy.

Admiralty metal (70 percent copper, 20 percent zinc, and 1 percent tin) appears under appropriate conditions to suffer from three distinct types of attack on the water side. These are dezincification (general and plug types), pitting (frequently at break in deposits), and impingement attack (at inlet ends at high velocities). When failure does not occur due to these forms of attack, there naturally occurs a general thinning over an extended period of time (Figures 4, 5, and 6).

Dezincification is probably the most important type of water-side corrosion of admiralty tubes in

* Registered trademark.

refinery service.* Evans has suggested that this form of attack takes place at the outset as follows:[2]

"At the outset, at places where the zinc and copper are distributed in a non-uniform manner, zinc is preferentially removed from anodic action—leaving, of necessity, copper-rich spots which can then serve as nuclei for the further deposition of copper. Then, on the main part of the surface, copper and zinc are dissolved out together by anodic attack, and the copper (alone) is redeposited as metal on the nuclei as cathodes."

Under conditions favorable to the attack, dezincification can take place over a uniform area. When local conditions alone favor the attack, such as non-uniform oxygen distribution, a form of "plug" pitting takes place. The plugs are redeposited copper. Plug type of pitting has been well described and illustrated by photographs by Wilkins, Bunn, and Lynes.[3]

Use of high-copper alloys, such as red brass, has been resorted to in order to avoid dezincification. Attack from the oil side has restrained this development—which, however, may be revived with the use of "duplex" tubes.

Comparative tests have shown that general dezincification can be suppressed by addition of such elements as arsenic, antimony, or phosphorus—and, to some extent, also by tin.

Pitting, inasmuch as it involves the formation of oxygen and metallic-ion-concentration cells, is a form of attack difficult to combat in the case of copper-alloy condenser tubes. This form of attack has been described well[4] by a prominent condenser-tube manufacturer as follows:

"If a foreign material is deposited on the tube wall, an electrochemically active cell may form, since in connection with the deposited foreign matter the opportunity for oxygen or the products of corrosion to concentrate is present. The formation of either an oxygen-concentration cell or a solution-concentration cell is apt to cause a rapid and intensive local pitting of the tube wall. A similar action may be initiated in other ways, as for example, a discontinuous coating of scale or corrosion product on the metal surface, surface defects, etc., resulting in general pitting, or an intense local pitting."

Impingement attack occurs usually at the entrance end of tubes through which the water is being circulated at high velocities. This form of attack has not been an important factor in the destruction of tubes in refinery condensers, although occasional instances of it have come to light.

Entrained air, and also air and gases liberated from the cooling waters, contribute to the destruction that results from impingement attack. The mechanism of cavitation frequently is present also when high turbulences of the water exist, and this furthers the work of destruction. Cavitation apparently depends upon the building up and collapse of low-pressure areas in the turbulent fluid. The presence of obstructions such as shells, metal filings, gravel, etc., is inducive of cavitation or impingement attack.

Mechanical means are invoked frequently in order to avoid impingement attack. Often a suitable vent will eliminate difficulty when the trouble is due to the presence of gases released from the water.

The copper-nickel alloys, with nickel contents of 20 and 30 percent, are becoming used rather widely in petroleum-refining circles, with 70-30 copper-nickel alloy apparently gaining in favor and becoming the more widely used. Some variations are provided by the use of 5 percent zinc in the 20-percent-

FIGURE 5
Showing Pitting as a Result of Deposit Attack (Magnification 3×).

nickel alloy or 1 percent tin in the 30-percent composition. However, the present trend appears towards the 70-30 composition without these additions.

The reports being received from the various in-

* Apparently, copper-zinc alloys containing more than 15 percent zinc are subject to dezincification.

stallations of the copper-nickel tubes indicate erratic behavior. In certain locations where these tubes have been installed to replace admiralty metal, which was failing as the result of dezincification, the

FIGURE 6
Showing Impingement Attack at Entrance of Condenser Tube (Magnification 3×).

results have been good. Success in other locations has been variable, depending upon the major cause of the tube corrosion and the ability of the alloy to withstand the particular conditions involved.

Investigation of the failure of a bundle of 80-20 copper-nickel tubes furnished indication that attack appeared to be predominantly of the impingement type. The presence of large amounts of sulfides in the scale on the inside (water side) of the tube led to the belief that the protective film was impaired by sulfur. Points at which the film was impaired may have been the focal point for initial attack, possibly of the cell type. It may be noted also that general experience has shown that the alloy with 20 percent nickel is distinctly inferior, in resistance to impingement effects, to the 30-percent composition. Consequently, the 30-percent alloy is indicated when such effects are predominant.

The bundle referred to previously failed in less than four months. Coastal water at about 120° F. passed through the tubes.

The unusually short-time life (about 11 months) of a bundle of 70-30 copper-nickel tubes made it desirable to study closely the failed tubes. The material contained 69.23 percent copper and 30.30 percent nickel, with 0.43 percent manganese and 0.01 percent iron. The very low iron content may have contributed to the early failure, as will be discussed later. The inner wall, which was contacted by contaminated—possibly brackish—coastal waters, was thickly covered with pits. The water reached a temperature of 160 to 170° F. An examination of the scale from the inner wall failed to reveal anything in the analysis to throw light on the causes of failure. Some sulfides were noted, but are assumed to have formed after the tube began to leak—from the petroleum side outward. The most probable immediate cause of failure seemed to be that the normally protective film at the inside (water side) was changed adversely during a short period of very high-temperature exposure when the water source failed. This also interfered with the reformation of the proper type of film when the water supply was restored. Under the resulting conditions, regions of varying potentials were formed that caused pitting.

Some fatigue failures of 70-30 copper-nickel tubes not associated with corrosion have been reported to have occurred in one instalation. The cause here was eliminated by supporting the tubes in such a manner as to dampen the vibration that caused the failures.

The particular merits of the 70-30 copper-nickel tubes are of practical value, when:

1. Dezincification is the primary cause of failure.
2. Impingement attack is a prominent factor.
3. Fairly wide variations in water composition and temperatures place unusual demands upon the condenser-tube materials.

Item (3) falls in the general classification of "hot spots" referred to by James T. Kemp[5] in his paper on the use of copper alloys in petroleum refining.

Reviewing the data at hand bearing on various installations of copper-nickel-alloy tubes throughout the country, and bearing in mind that these tubes usually are installed in locations where other types have failed, it can be said that they offer a real contribution to refinery condenser operation. A life of 2.5 to 6 times that obtained from admiralty tube often is obtained from the copper-nickel tubes. (It will be noted also that the copper-nickel tubes are giving a good account of themselves in oil-to-oil exchanger service under trying conditions.)

The effects of small percentages of iron and manganese, as well as the ratio of these elements to each other, appear to affect the behavior of the

copper-nickel alloys. According to F. L. La Que:[6]

"Tests are under way to study the effects of minor constituents, principally iron and manganese, on the ability of the 70-30 copper-nickel alloy to resist impingement effects and other types of sea-water attack. Results already available are in good agreement with those of similar tests and practical experience abroad. They indicate that the minimum iron content should be about 0.3 percent, and that the manganese content should exceed the iron content. There has been no evidence that such common upper limits on iron and manganese as 0.50 percent and 1.00 percent, respectively, need be changed."

The general employment of copper-nickel tubes in refineries is fairly new, and some time must elapse before the usefulness of these alloys is truly defined. gested "deposit attack." It was noted, however, that orientation of some of the pits indicated the presence of some turbulence in the water. It should be emphasized that failure occurred chiefly from the oil side. The foregoing is introduced to indicate the depth and extent of pittng to be expected in this area during the period of time covered. Indications are that the depths of pits have not increased materially during the four months the tubes served, after one was withdrawn at the end of the eighteenth month. As a general rule, pitting of this alloy is most likely to occur at low water velocities or when the flow of water may be interrupted for periods of several days.

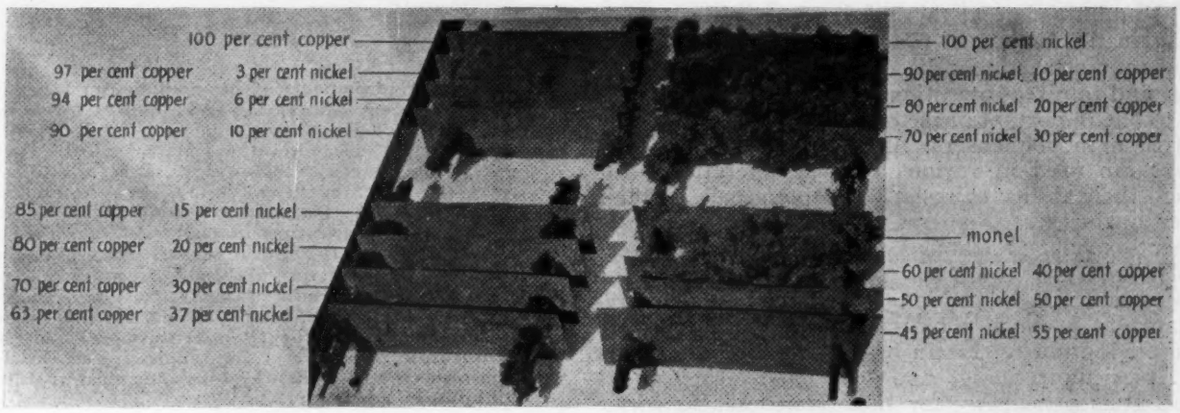
100 per cent copper
97 per cent copper 3 per cent nickel
94 per cent copper 6 per cent nickel
90 per cent copper 10 per cent nickel
85 per cent copper 15 per cent nickel
80 per cent copper 20 per cent nickel
70 per cent copper 30 per cent nickel
63 per cent copper 37 per cent nickel
100 per cent nickel
90 per cent nickel, 10 per cent copper
80 per cent nickel 20 per cent copper
70 per cent nickel 30 per cent copper
monel
60 per cent nickel 40 per cent copper
50 per cent nickel 50 per cent copper
45 per cent nickel 55 per cent copper

FIGURE 7
Effect of Nickel Content on the Fouling Characteristics of Nickel-Copper Alloys in Sea Water. (Rods running through specimens are monel—69 percent nickel, 29 percent copper.)

Reports on tubes such as submitted by E. S. Dixon[7] are quite helpful in the effort to evaluate correctly the service of copper-nickel and other alloy tubes, and should be encouraged.

Monel (67 Percent Nickel, 30 Percent Copper)

Several bundles of monel condenser tubes have entered refinery service. The use of monel has been dictated largely by some characteristic of the material being cooled. However, monel possesses a resistance to corrosive waters that has influenced its selection in many cases.

The behavior of monel tubes, for the most part good, has been marked by some premature failures. One of the failures was associated with locked-up stresses in the tube walls. These stresses, released by some corrosion, caused ruptures in the walls—thus prematurely retiring the bundle.

An installation on the Gulf Coast failed completely after about two years' service, due mainly to vigorous atack from the oil side. However, considerable pitting occurred on the water side (inside). Examination of the failed tubes has not been completed. However, examination of a tube from this bundle that was perforated after 18 months' service showed a thick, uniform, brown coating. Beneath this coating, and next to the metal, some red cuprous oxide and some greenish areas existed. The brown corrosion product was analyzed qualitatively, and large amounts of iron, copper, nickel chlorides, and sulfates were detected. Underneath the corrosion products, the metal surface was pitted profusely. The deepest pits varied from 0.009 to 0.013 inch deep (0.065-inch walls). The type of pitting sug-

An interesting feature of the copper-nickel and nickel-copper alloys is the relatively sharp region in the copper contents that permits the growth of sea organisms upon the metal. It will be noted (Figure 7) that growth occurs when there is 0 to 40 percent copper. From 40 to 100 percent copper, there tends to be no growth—due apparently to the presence of sufficient copper in the products of corrosion. This observation may be of special interest in connection with the submerged-unit type of condenser that appears to be increasing in popularity. In this condenser, bundles of tubes are installed in an open box which is kept full of water. The oil passes inside the tubes. It will be observed (Figure 7) that monel is not "self-cleansing," whereas the 70-30 copper-nickel alloy is.

Case histories of monel bundles are limited; and, due to the ratio of the cost of monel to that of admiralty (about 4-5 to 1), no general use of the alloy is likely. Undoubtedly it will be used more widely as the chemical activities of the refineries grow and makes demands for alloys resistant to certain specific materials.

BIBLIOGRAPHY

[1] W. A. Wesley, H. R. Copson, and F. L. La Que, "Graphitic Corrosion of Cast Iron," Metals & Alloys, 325, Dec. (1936).
[2] F. W. Fink, "The Dezincification of Alpha Brass with Special Reference to Arsenic," Trans. Electrochem. Soc. 75, 447, discussion by U. R. Evans (1939).
[3] R. A. Wilkins, E. S. Bunn, and W. Lynes, "Corrosion of Copper and Copper-Base Tubing in Oil-Refinery Heat-Transfer Equipment," Proc. API 21M [III] 46 (1940).
[4] Heat Exchanger Tube Manual, 7, Scovill Manufacturing Co., Waterbury, Conn.
[5] James T. Kemp, "Copper Alloys and their Application in Petroleum Refining," Proc. API 21M [III] 58 (1940).
[6] F. L. La Que, "The Behavior of Nickel-Copper Alloys in Sea Water," J. Am. Soc. Naval Engrs. 53 [I] 29 (1941); reprinted by The International Nickel Co., Inc., New York, N. Y.
[7] E. S. Dixon, "Service and Life of Non-ferrous Tubes in Petroleum Refining," Am. Soc. Testing Materials Bull. 102, Jan. (1940).

Corrosion of Copper-Alloy Condenser Tubes by Water

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MORE replacements of brass condenser tubes in oil-refinery service are said to be caused by corrosion by the cooling waters used than by destructive attack by the oils and vapors being cooled. When stream-side corrosion does occur, it is apt to act more quickly. Some common refinery design and operating practices are thought to hasten water-side corrosion. Several copper-base-alloy tubes are available and are used. Admiralty-metal tubes predominate, and are used with all kinds of cooling waters. A simple classification of water-side corrosion on the basis of visible effects is offered and illustrated. Dezincification can be avoided in some cases by substituting other alloys for admiralty, or can be diminished considerably by using arsenical or other "inhibited" admiralty alloy.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

IT IS appropriate at this mid-year meeting to pick up again the subject of the copper-base metals used in oil refining, actively discussed at Fort Worth last year, and to direct attention in a more detailed manner to one important phase of the subject—water-side corrosion in condensers. Although the copper-base alloys are used in various refinery operations—for which their ability to resist corrosive attack or their other qualities recommend them—their main use is in heat-exchange apparatus, principally in condensers cooled by water. Good resistance to corrosion by the vapors and the impurities carried by them and resistance to destruction by water are qualities that led to the adoption of certain brasses in the early years of American refining, and of copper-nickel alloys later. It is principally for their resistance to corrosion by water that the brasses are used in condensers, although their resistance to attack by steam condensation on the vapor side—condensation that becomes charged with chlorides, sulfides, sulfates, and neutralizers—also is very important.

Judged by the cases of tube failure that come to the attention of the technical staff of The American Brass Company, tube failures are twice as frequent on the stream side as on the water side. Jamison, however, in his notable report on "Corrosion Protection for Refinery Equipment," submitted at the annual meeting in Chicago in 1938, stated that: "The water, ever-changing in composition and brackish in nature, accounts for the chief source of corrosion—causing failures of admiralty metal by pitted dezincification." Jamison's estimate is based on an extensive survey of the industry in the United States; and, even though condensers were but a part of his concern, his remark must be taken as a fair general statement of conditions, at least insofar as it applies to the source of the greatest tube destruction. The tube maker seldom sees the run of refinery discards, although cases of unusually short tube life often are brought to him. It is, therefore, natural for a tube maker to form the opinion that stream-side corrosion takes the greatest toll. Stream-side corrosion, when it is severe, probably acts more quickly than that on the water side. Stream-side corrosion offers a great variety of difficult cases to diagnose.

Water Supplies and Alloys

Very few refineries have adequate supplies of pure water for cooling. Refinery corrosion difficulties are greater, therefore, than those experienced by most other industries. The available fresh-water supplies are often inadequate, and must be conserved by closed-circuit circulation including forced cooling in towers. The descending spray of cooling water picks up sulfur compounds, carbon dioxide, and an abundance of oxygen from the atmosphere. Abnormal concentrations of mineral salts may build up. Salt ocean water is more corrosive than fresh water. Brackish water, generally speaking, is worse than either. Tidal water in closed bays, and in the lower reaches of rivers during dry seasons, become brackish because the sluggish flow does not displace standing water with generous supplies of new water. Such a situation permits accumulation of city drainage and plant wastes in the water, befouling the water and increasing the active corrosion of the metal of pipe lines, pumps, and exchangers.

Condenser tubes are commercially available in ten or a dozen alloys. Many of these alloys, however, are not well suited to the vapor side; but those that are so suited are sufficient in number to offer refiners some choice of corrosion-resisting properties on the water side. Prominent among the alloys used in oil refineries are:

Admiralty metal
Red brass
Cupro nickel
Aluminum brass

Practically 80 percent of the non-ferrous condenser tubes used in American petroleum refining are of admiralty metal. This tin-bearing brass is remarkably successful with all kinds of waters and in all types of condensers. In instances when oxygen saturation of tower-cooled fresh water has caused undue corrosion of the "dezincification" type, the substitution of arsenical admiralty or red brass—15 percent higher in copper— has diminished or ended this trouble. Salt harbor waters have been handled by 70-30 cupro-

nickel, with some success in refineries in the North Atlantic area, and by aluminum brass in the southern Caribbean. Other tube alloys—such as the coppers, plain and arsenical; Muntz; aluminum bronze; and Everdur—have fields of usefulness, but do not

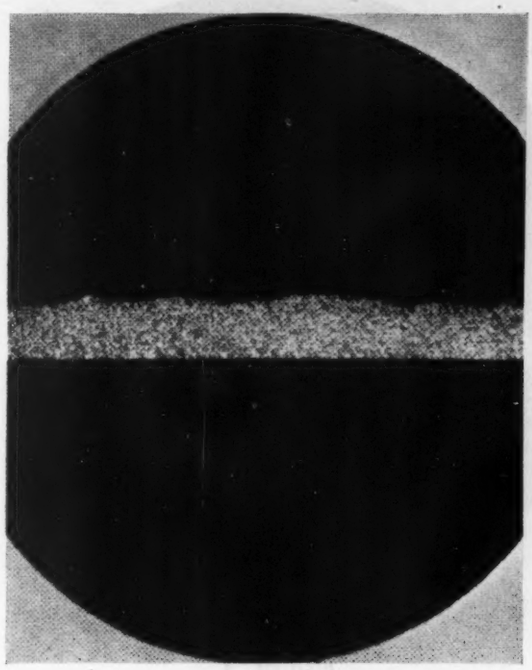

FIGURE 1
Lengthwise Section Showing General Wall Thinning—Fresh Water, Admiralty Metal (10 Diameters).

FIGURE 2
Lengthwise Section Through an "Island"—Admiralty Metal, Salt Water (75 Diameters).

combine the necessary properties on both sides to have important places in refinery-condenser practice.

What is the standard of success by which are judged red brass, super-nickel, aluminum brass, or the dozen special tube alloys that have been tried? Broadly speaking, it is whether the alloy is as long-lived or longer-lived than admiralty metal in actual refinery operation. Practically there is no other standard of direct comparison, unless it be between banks of brass tubes and coils of cast iron or, more rarely, banks of steel pipe in submerged condensers. By experience we have found that Muntz metal tubes should not be used in water-cooled oil-refinery condensers; that tubes of either deoxidized or arsenical copper should not be used with salt or brackish water. Red brass and the copper-silicon series of alloys (Everdur) should be included in this group. The copper-nickels may be used with either fresh or salt water; red brass, as noted previously, with fresh water if plain admiralty dezincifies rapidly. Aluminum brass is a salt-water alloy; it does not seem to have notably better properties than admiralty in fresh water.

Influence of Design

To a metallurgist not very familiar with the details of refinery operation, there seems to be much in re-

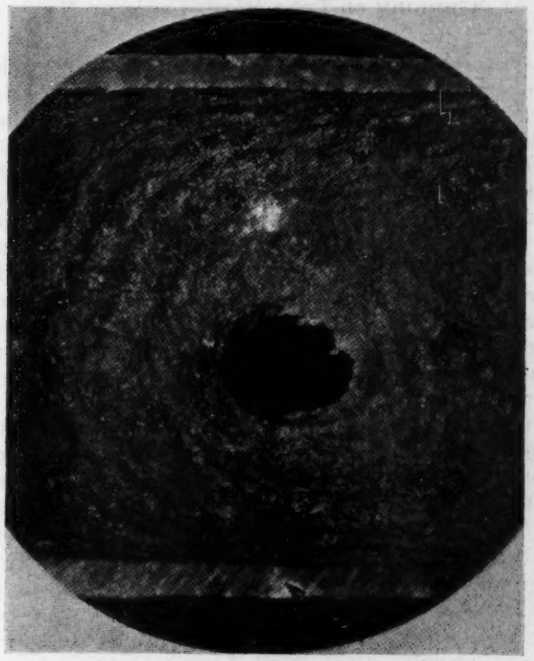

FIGURE 3
Admiralty Tube Pitted to Perforation—Atlantic Ocean Water (4 Diameters).

finery layout and equipment design that favors corrosion of condenser tubes. Three things may be mentioned herein: 1, the common practice of raising the cooling-water temperature almost to the boiling point by cascading shell-and-tube condensers, or by slow flow through the boxes of submerged condensers; 2, the very low water velocities within condenser tubes; and 3, the close packing of tubes in bundles. Each of these matters appears to have played a definite part in assisting the early destruction of tubes in cases brought to our attention. Each of these customs of the refinery can be supported by citing original cost, pumping cost, or need for close temperature control in some heat extraction operation. The trend in steam-condenser design is toward open-tube arrangements, simple circulating paths, and velocities three to four times those common in refineries. Tubes last much longer in steam condensers, even those

handling the same cooling-water supply as is used for refinery process cooling. It is natural, therefore, to ask the question: "Would not a shift toward steam practice be advantageous in refinery equipment—at least when the problem is simply that of abstracting heat from a condensing vapor stream?"

Forms of Water-Side Corrosion

The most easily recognized characteristics of corroded condenser tubes offer a simple means of classifying water-side attack.

1. Thinning of the tube wall, metal remaining but lightly covered with deposits:
   a. Uniform and widespread.
   b. Localized, pitting.
2. Attack marked by characteristic residual-corrosion products:
   a. Dezincification, redeposited copper.
   b. Chemical attack, metallic compounds.
3. Sub-surface penetration:
   a. Selective corrosion as in Muntz metal.
   b. Grain-boundary attack.
4. Corrosion cracking.
5. Erosion.

1. Thinning of Tube Wall, Little or No Surface Deposits

a. *Widespread Corrosion*—In the simplest corroding action the tube wall is dissolved in a more or less uniform manner, leaving a fairly smooth surface. Corrosion products either do not form or they establish protective films; the metal constantly is exposed to attack. If a local protective film or cover is established, high spots or areas of nearly full wall thickness will be found in the tube. This type of attack can be caused by acids or by industrial wastes in the water. It sometimes occurs with apparently clean salt water. It is hastened by the abrasive action of suspended solids, but rarely is the result of external galvanic action. Figure 1 is a lengthwise section of such an admiralty tube from a Kansas natural-gasoline plant. Figure 2 is a section through one of many "islands" on a tube that operated in salt water in a South Texas coastal refinery. This tube had been "cleaned" several times with hydrochloric acid.

b. *Localized Corrosion—Pits*—Pitting is one of the more common forms of destruction. Several kinds of pits are recognized. "Impingement" pitting or the "corrosion erosion" of marine or steam-power condensers seldom is found in refinery condensers. This type is associated with much higher water velocities entering and within the tubes than are usual in refinery practice. Pits may be started by loose debris carried into and deposited on the tubes, such as cinders, coke, other metals, bits of shell, air bubbles that attach themselves to the tube walls, etc. These foreign materials and loosely formed porous corrosion products may set up differential aeration cells that lead to pitting. Pits may be numerous—in compact areas, or they may be few and widely scattered.

Figure 3 is an isolated pit that perforated an admiralty tube in a refinery in New England which uses salt water. Figure 4 is a lengthwise section of a red-brass tube handling Houston Ship Channel water.

2. Attack Marked by Characteristic Residual-Corrosion Products

a. *Dezincification*—Corrosion characterized by conspicuous residual products properly warrants more detailed study than we can give it here. Two general types of such corrosion are recognized, but they overlap to such an extent that no clear classification on the basis of residual products alone can be made in every instance. The type known as "dezincification" is familiar. It is recognized easily by the brick-red color of the "redeposited copper" or the "plugs" on

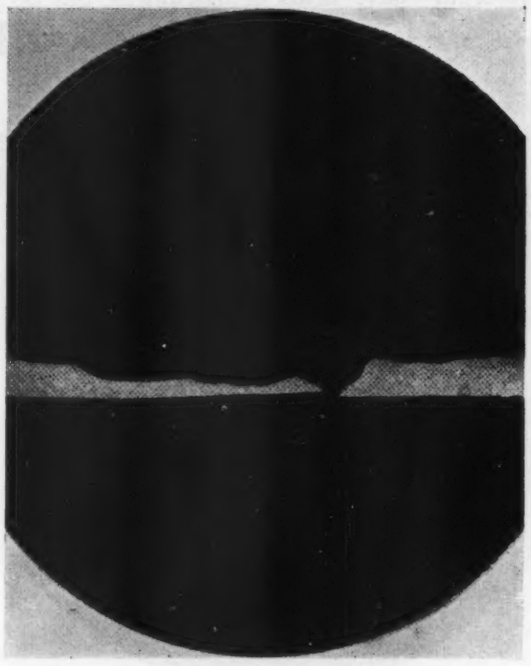

FIGURE 4
Lengthwise Section of Red-Brass Tube, Pitted by Houston Ship Channel Water (5 Diameters).

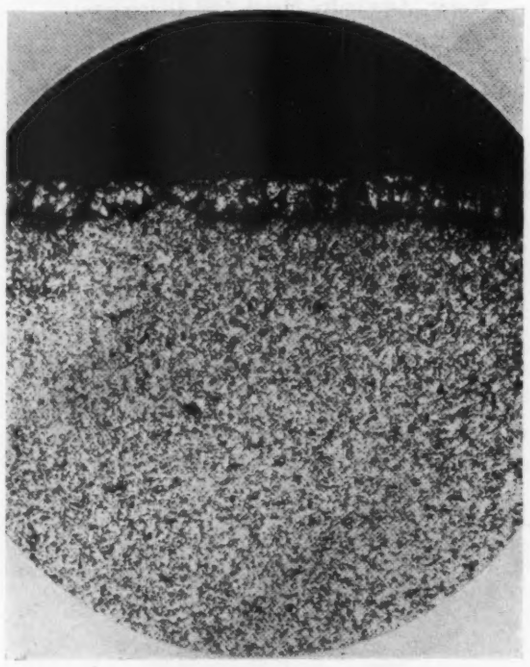

FIGURE 5
General Surface Dezincification—Spray-Tower-Cooled Water, Oklahoma (75 Diameters).

the tube surface or through the whole tube wall. The name is an unfortunate one, in that it implies that the zinc in a brass is there in such a state that it can be removed separately without disturbing the copper of the alloy. Such a condition does not exist in any wrought brass. The zinc is distributed uniformly, in solid solution, throughout the entire mass of metal.

The atoms of zinc are integral parts of the crystalline alloy structure. The popular explanation of "dezincification" is that the alloy is dissolved slowly—both copper and zinc being taken up—but that the solvent water is not as capable of holding the copper in solution as it is the zinc. The zinc escapes in solution in soluble compounds, or may accumulate in masses of insoluble carbonates; but the copper is "redeposited" in metallic form. The redeposited copper is somewhat porous, and does not protect the underlying metal—but, instead, by virtue of its porosity, encourages further action. This brief statement omits all reference to chemical action or to the minute electrical actions that may be a part of the mechanism. Dezincification occurs in all waters; and is hastened by mild corroding agents, by dissolved oxygen, by elevated temperatures. Brasses richer in copper than 80 percent are seldom "dezincified." Cases of redeposition of copper on alloys higher than 85 percent and on alloys with little or no zinc, but with nickel or silicon, have been observed occasionally. In the refinery the "dezincification" of admiralty condenser

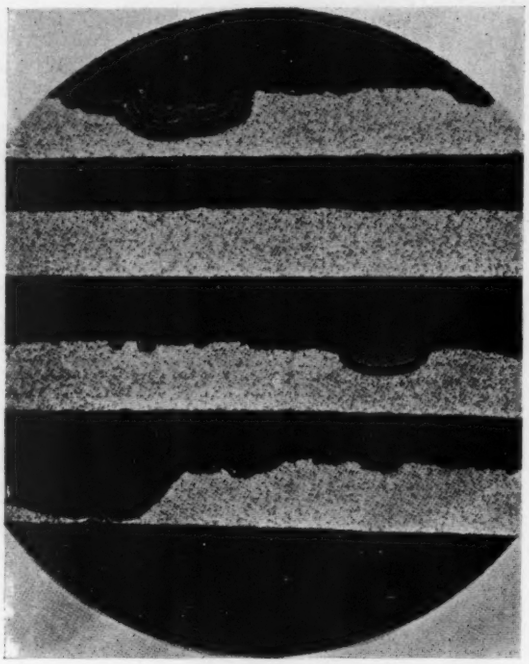

FIGURE 6
Plug-Type Dezincification in Admiralty Tube—Befouled Fresh to Brackish Water (6 Diameters).

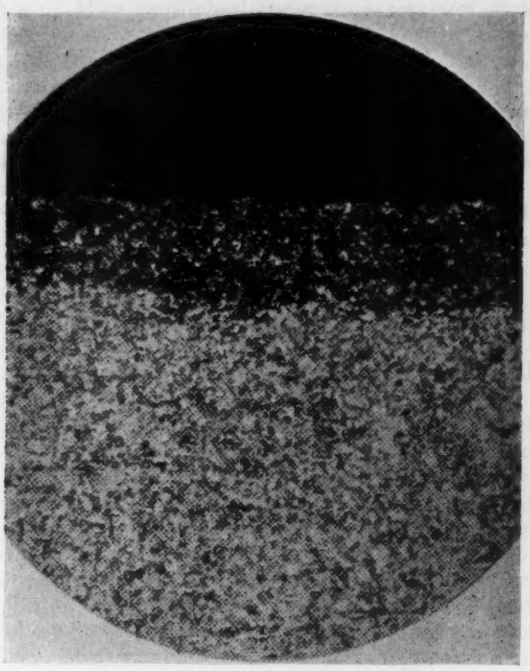

FIGURE 8
Rare Case of Red-Brass Dezincified by Brackish Salt Water (75 Diameters).

FIGURE 7
Outer Surface of Admiralty Tube, Showing Penetration by Plug-Type Dezincification (3.5 Diameters from the Inside).

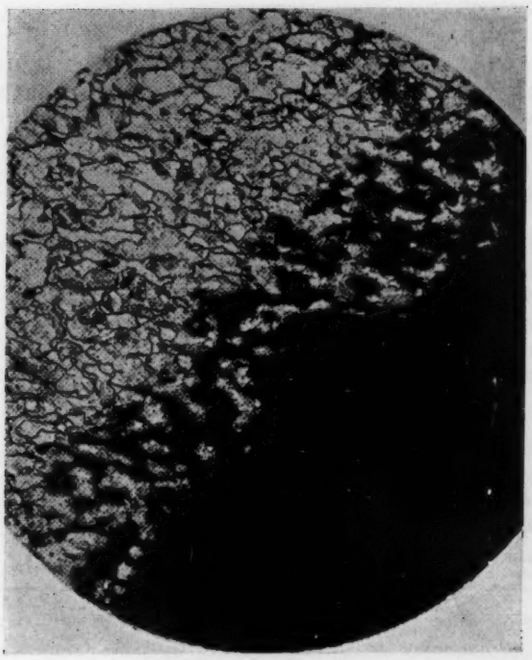

FIGURE 9
Inside Surface of Muntz-Metal Water Pipe—Selective Corrosion of Beta (75 Diameters).

tubes may be either general or "plug-type." Figure 5 illustrates a typical early stage of general surface dezincification of admiralty tube by tower-cooled fresh water in Oklahoma. Tubes that are attacked in this way may dezincify through the entire wall. Figure 6 is a group of sections showing plug-type dezincification in admiralty metal from a refinery using Houston Ship Channel water. The copper plug has fallen out of the largest pit in the lower sample. Figure 7 illustrates a bad case of plug-type dezincification, in which the plugs have penetrated the tube wall. One plug has loosened. This is from a refinery in northwestern Pennsylvania. Figure 8 illustrates a rare case of general dezincification of red brass by brackish salt water in a Texas coast refinery.

A great deal has been said in the last few years about the prevention of dezincification by manipulation of the alloy. A great deal of importance has been accomplished in this direction by systematic researches conducted by brass-mill metallurgists. The first "inhibitor" intentionally used by brass makers was tin. At some time in the early 1880's it was

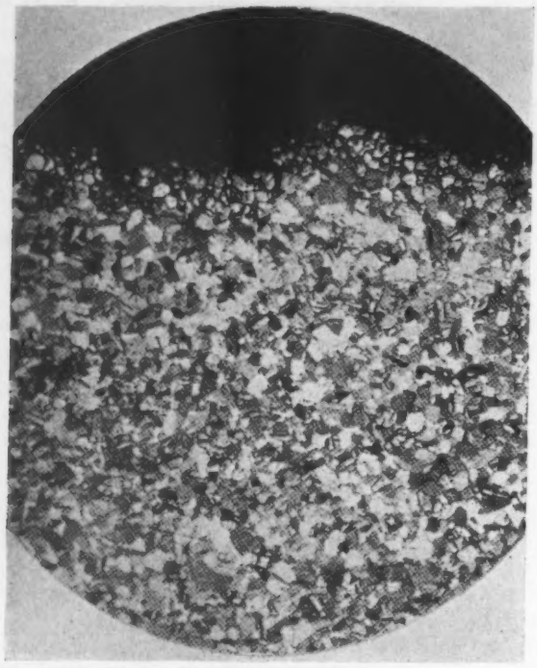

FIGURE 10
Lengthwise Section, Admiralty Condenser Tube—Intergranular Penetration (73 Diameters).

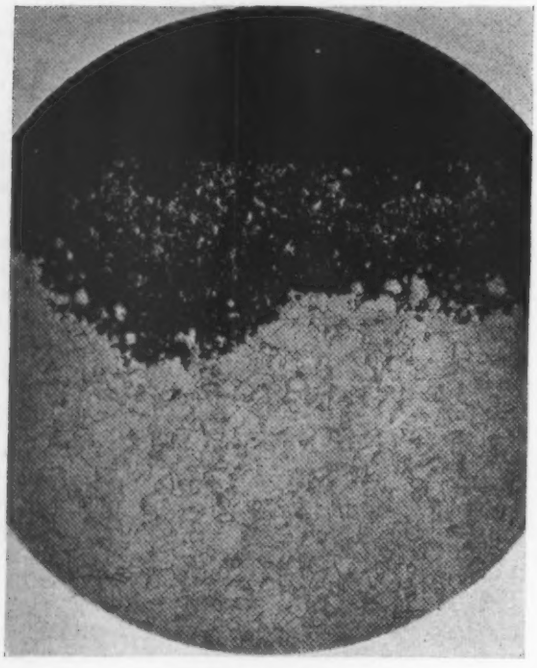

FIGURE 11
Intergranular Penetration of Admiralty Tube in Advance of Plug-Type Dezincification (75 Diameters).

FIGURE 12
Intergranular Corrosion in an Admiralty Tube with Transcrystalline Crack Below (75 Diameters).

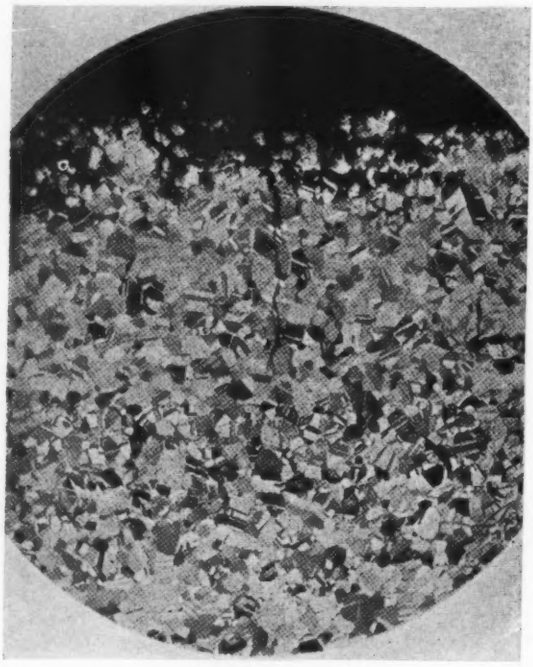

FIGURE 13
Lengthwise Section of an Admiralty Tube Cracked by Ammonia Gas (75 Diameters).

observed in England that the addition of about 1 percent of tin to 60-40 and 70-30 brasses improved their resistance to sea-water corrosion without interfering with their valuable physical properties. The former came to be known in its two varieties as naval

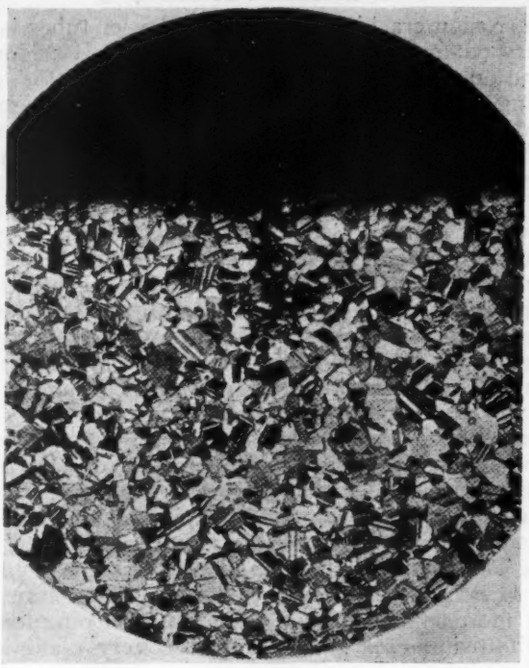

FIGURE 14
Lengthwise Section of an Admiralty Tube Cracked by Mercury (75 Diameters).

brass and Tobin bronze—the latter "admiralty metal" in deference to the preference given to condenser tubes made of it by the constructors of the Royal Navy. Recently active attention has turned toward the beneficial influence of certain minor elements, viz., arsenic, antimony, and phosphorus, added to admiralty metal in definite though small amounts. Very definite retardation of dezincification under average condenser operating conditions has resulted from the use of these additions or "inhibitors." In a sense, this is a return to the metal of the fire-refined copper era prior to 1900, before electrolytic copper of high purity and high conductivity became the common copper of commerce. The common "impurity" in late 19th-century fire-refined copper was arsenic. Brass condenser tubes of that day, therefore—whether Muntz metal, 70-30, or admiralty metal—were arsenical. The benefits conferred by this element, however, were not suspected. In 1924 Bengough and May published their investigation of the influence of several additions to 70-30 brass on corrosion in sea water in the monumental "Seventh Report of the Corrosion Committee of the Institute of Metals." They found arsenic effective in preventing dezincing; and stated further that "tin, nickel, tungsten, antimony, and aluminum have an effect of the same kind as arsenic, but less intense and in the order named." None of the examples of corroded condenser tubes illustrating this paper contained arsenic. Only one, that shown in Figure 15, was "inhibited."

b. *Metallic Compounds*—Corrosion of the kind that leaves significant amounts of metallic compounds on the water-wet face of a condenser tube is essentially a chemical action. Identification of the products of corrosion is a regular part of the metallurgical examination of a used tube. Such products afford direct clues to the destructive agencies. Worn-out refinery condenser tubes are almost always lined with crusts, films, and deposits of the chlorides, sulfides, and sulfates of the major component metals. Both cuprous and cupric oxides are common, the latter when there is an abundance of oxygen in the water. Other salts may be present. Usually there are also generous quantities of rust, clays, silica, and organic matter which may or may not be significant.

3. Sub-Surface Penetration

a. *Selective Corrosion*—Sub-surface penetration is a subtler form of corrosion and one as yet not well understood. At least two kinds are recognized. In two-phase alloys, of which Muntz metal is the common example, the second or copper-lean phase (beta) corrodes more readily than the copper-rich phase (alpha). Metallographically speaking, a phase has no definite composition, but is a solid solution embracing a range of solute concentration. The copper-rich alpha phase in brass extends from pure copper to approximately 62 percent at room temperature. Figure 9 illustrates an example of corrosion of Muntz metal by water, in which the lower copper beta matrix has been attacked in depth—leaving a skeleton formation of the remnants of alpha grains standing in their original positions. In a case of this kind

TABLE 1
Type of Composition of Commercial Copper-Alloy Condenser Tubes
(All Figures in Percent)

	Copper	Tin	Aluminum	Nickel	Zinc	Manganese (Maximum)	Lead (Maximum)	Iron (Maximum)	Arsenic, Etc. (Maximum)
Admiralty	70.0 to 73.0	0.90 to 1.20	.....	.....	Remainder	..	0.075	0.06	.....
Admiralty, arsenical	70.0 to 73.0	0.90 to 1.20	.....	.....	Remainder	..	0.075	0.06	0.10*
Red brass	84.0 minimum	.....	.....	.....	Remainder	..	0.075	0.06	.....
Aluminum brass	76.0 minimum	.....	1.75 to 2.50	.....	Remainder	..	0.075	0.06	.....
Super-nickel	Remainder	.....	.....	29.0 to 33.0	1.0 maximum	1.0	0.05	0.5	.....
Cupro-nickel	Remainder	.....	.....	19.0 to 23.0	1.0 maximum	1.0	0.05	0.5	.....
Ambrac	Remainder	.....	.....	19.0 to 23.0	3.0 to 6.0	1.0	0.05	0.5	.....
Aluminum bronze	93.5 minimum	.....	5.00 minimum	.....	.....	..	....	.....	.....
Everdur 1010	96.0	.....	Silicon 3.00	.....	.....	1.0	....	.....	.....
Everdur 1015	98.25	.....	1.50	.....	.....	0.25	....	.....	.....
Copper, deoxidized	99.90 minimum	.....	.....	.....	.....	..	....	Phosphorus, 0.035 maximum	.....
Copper, arsenical	99.45 minimum	.....	.....	.....	.....	..	....	.....	0.15 to 0.50
Muntz metal	59.0 to 63.0	.....	.....	.....	Remainder	..	0.3	0.07	.....
Tobin bronze	60.0	0.75	.....	.....	Remainder	..	....	.....	.....

* Antimony or phosphorus in antimonial or phosphorized admiralty, 0.10 percent maximum.

the difference in copper content of the two phases is probably not more than 2 or 3 percent at the most. This example is not from a refinery, but is a Muntz water pipe that failed 10 years ago in eastern Pennsylvania.

FIGURE 15
Outside of an Eroded Admiralty Condenser Tube From an Atmospheric Cooler, West Texas (Natural Size).

b. *Grain-Boundary Attack*—Admiralty metal occassionally suffers from a grain-boundary penetration of the kind seen in Figure 10. This tube was removed from a naphtha cooler in a Texas coast refinery after five months' operation. The water was fresh to brackish. Occasionally a similar condition is observed accompanying dezincification. Figure 11, an admiralty tube from a northwestern Pennsylvania refinery, shows intergranular penetration ahead of plug formation.

We have no satisfactory explanation for intergranular corrosion. There have been circumstances that suggest some relation to stress corrosion, such as the transverse transcrystalline cracks penetrating the tube wall from an affected area, as seen in Figure 12. Others suggest action not unlike that of ammonia.

4. Corrosion Cracking

Corrosion cracking of brass condenser tubes is not a very common occurrence in refineries. It seldom is found on the water side. One common cause is overrolling of the ends, the rolling extending enough beyond the tube sheet to form a ridge in the outer tube surface. Cracks from this source follow the ridge. In assembling bundles, stresses can be set up by sticking floating heads, or by temperature differential within a bundle. Seldom are such stresses great enough to make tubes liable to cracking. Identification of stress corrosion cracking depends upon the similarity of the conditions found to those known in cases of the same type. When the cracks are not associated with easily identifiable causes, for example over-rolling, some knowledge of the equipment and the working conditions is necessary for definite identification. Figures 13 and 14 illustrate examples of corrosion cracking caused by ammonia and by mercury. Figure 13 illustrates a tube from an exchanger bundle, wrecked by an unwise test of a piping setup, using a mixture of ammonia and air for pressuring the system. The destruction of the bundle (from which Figure 14 was taken) followed the accidental emptying of a mercury-filled manometer into the pipe leading to this condenser in a solvent-recovery plant in an eastern lubricating-oil refinery.

6. Erosion

Erosion is another rare form of destruction of the water side of refinery condenser tubes. It is not uncommon at the entrance ends of tubes in steam condensers in which the water velocities through the tubes exceed 7 or 8 feet per second. More than a high velocity of water alone is necessary to set up erosive action. Erosion of a sort, however, is not uncommon on the outside of tubes in atmospheric coolers or in condensers built into the bases of cooling towers. Figure 15 is a photograph of the water side of an admiralty tube deeply eroded by falling water in a West Texas topping and cracking plant.

Conclusion

There is always danger that a paper of this kind, dwelling on the forms of corrosion of a series of alloys and illustrating their weaker properties, may create the impression that these metals are not well adapted to the rough service of oil refining. Quite the opposite is true. The metallurgist, as mentioned earlier in this discussion, has the conspicuous failures presented to him. He writes a paper about them. But all the time thousands of brass tubes are condensing gasoline in thousands of condensers, and these tubes are living out their expected terms without attracting attention. The failures, nevertheless, should be studied in the hope of avoiding other similar ones. If early failures can be avoided by change of alloy or by the correction of some unfavorable operating condition to insure longer tube life or fewer interruptions of production, the industry benefits thereby.

Characteristics of *Microbiological Deposits* in Water Circuits

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AN OUTLINE of theories offering possible explanations for some types of corrosion in water circuits, a description of processes involved in bio-fouling, and the analyses of characteristic deposits are given, together with suggestions as to the importance of clean surfaces prerequisite to successful application of corrosion-prevention and control methods.

A biological approach is emphasized to the extent that accumulated knowledge of the ecology, morphology, and physiology of specific organisms and groups of organisms is held as most important in analyses of fouling and corrosion problems. Consideration is given to some more important contributions to this phase of existing knowledge, and recommendations for their evaluation and utilization are covered briefly.

Emphasis is placed on correlation of related physical, chemical, electrochemical, biochemical, and biophysical phenomena.

Illustrative references to contemporary use of chlorination for control of microbiological growths are included, with comment on the interrelation of concrete and metal corrosion, and on problems of maintaining capacity in various types of water circuits.

Need for corrosion control in clean refinery water circuits is stated; and reference is made to adjustment of pH, elimination of true scaling, maintenance of uniform surfaces, and development of protective coatings as being worth special consideration after clean water-circuit surfaces have been obtained.

This paper was presented to Division of Refining, before the Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

THE viewpoint of biologists is essential to well-rounded studies of matter whenever moisture is present and when temperatures approach a range in which human being can survive. The importance of physical and chemical effects of expanding, contracting, eroding, heating, straining, oxidizing, reducing, and electrolyzing processes has been stressed to exclusion of other critical factors.

Microorganisms can grow in most water circuits, and in the same locale where electrochemical corrosion occurs. Many organisms are important to natural disintegrations. The work of lichens in fracturing rocks and their part in geological process are an obvious example.

Beginning with work of Ehrenberg in 1826,[51] and Cohn in 1870,[52] the literature shows numerous appraisals of iron-depositing bacteria.

The observations of Ellis[58] in 1917 paved the way

FIGURE 1
Photomicrograph—Crenothrix in Slime (Magnification, Approximately 400×) "The Well Pest."

for the classical works on crenothrix and limonite which were reported by Harder[57] in 1919.

Winogradsky[53] in 1887, Van Delden[55] in 1904, and later Ellis, call attention to the importance of sulfur bacteria. Evidence that many bog-iron and some sulfur deposits have been accumulated in past ages as a result of variegated growths of bacteria is incontrovertible. (Allied organisms are placed under these two broad classifications.)

"Water Calamity," "Water Sickness," "Well Pest"

K. Kraepelin[34] made extensive studies of Hamburg "pipe fauna" several years before the epidemic of 1892. The concept of growth predominates in the early literature as a working background for consideration of water-system depositions. There is frequent reference to "water disease" and to the causative organisms as "well pests," and to the sum total effect as "water calamities."

The whole collection of organisms familiar to early workers is present in the large modern industrial plant: service water supply; processing units (including food); paper-making machines; heat exchangers;

steam condensers and waste-disposal works. The positions of most of the organisms of interest in this connection are shown by a quasi-popular classified arrangement in the chart of water fauna and flora.

The chart rectangles include bacteria, fungi, algae, etc., combining to agglomerate organic and inorganic matter as deposits of slime or bio-fouling in refinery water circuits. It has been stated that there are more than 100,000[35] varieties of fungi. Few of these have been studied to the extent that their morphology is understood sufficiently to allow exact identification. In addition, there are many polymorphic forms and symbiotic combinations to be considered. These may be similar to algae and fungi growing together as lichen.

Soil microbiologists study the ecology, morphology, and physiology of related organisms with respect to transformation of soil, water, and gases into plant food.

Prolific growths in some of the prominent groups are responsible for spread of water-borne diseases including some newly recognized milder afflictions: slime, scale, encrustations, and corrosion.

By 1914 the science of water biology had developed to a stage such that Whipple[35] indicates a bibliography of the subject might occupy 100 pages. The intense interest in this field held by technicians and engineers from 1850 (Cohn) to 1905 (Brown) follows as a matter of course, inasmuch as manipulations of environmental conditions and the application of self-

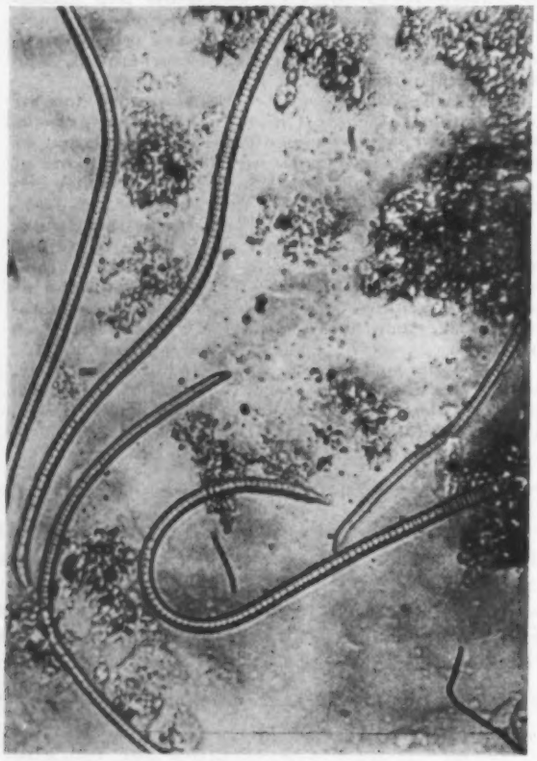


FIGURE 2
Masses of Fungi, Crenothrix, and Sphaerotilus Have Been Described Erroneously as Oscillatoria—an Alga (Magnification, Approximately 400×).

purification principles were depended upon to control water-borne diseases.

Because of its juxtaposition with Altona, the Hamburg cholera outbreak gave classic proof that such diseases as typhoid fever, dysentery, and cholera are spread through unprotected and untreated public water supplies.[9] More than anything else, this epidemic stimulated interest in chemical sterilization. Pioneer work on chlorination was done in Belgium, Holland, and England. Sims Woodhead[2] used chlorine at the Maidstone filter plant during an outbreak of typhoid fever in 1897, and Sir Alexander Houston's

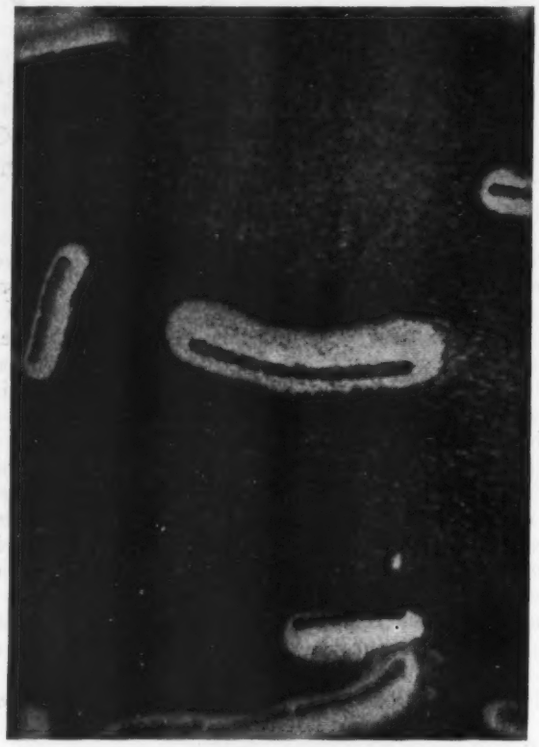


FIGURE 3
Capsulated Bacteria—Develop as Mucoid Colony and Provide Gelatinous Slime Binder (Magnification, Approximately 900×).

use of sodium hypochlorite in 1904 and 1905 at the Lincoln filter plant was his first of many contributions to the art of chlorination.

A considerable group of men living in New England, and working together from 1875 to 1910, made invaluable contributions to sanitary engineering. Prominent among them were Mills, Clark, Sedgwick, Whipple, Stearns, Winslow, Phelps, Hering, Kinnicutt, Hazen, Goodenough, and Fuller. Use of rapid sand filters and other treatment processes brought tremendous reductions in organisms distributed through water systems. Improvements were so satisfactory that the numbers of organisms left for seeding were ignored.

When virtually untreated waters are used in industrial-plant processes, or polluted waters are handled for disposal, there are recurrences of "water calamities." For example, Figure 5 shows fouling of water-supply screens from a chlorinator wherein contaminated water is used to operate chlorine-control apparatus. Yet, it was not until 1932, when Reddick's and Linderman's[115] presentation was heard by J. T. Robertson[84] of Utica, New York, that interest in controlling system growths again received publicity and reached importance.

Fouling of Water-Supply Systems—Mains and Filters

In studying degradation of hydraulic structures supplying Liverpool, Campbell Brown and Sir Rupert Boyce[68] found filaments of crenothrix in the gelati-

nous lining that had decreased pipe-carrying capacities some 15 percent. They observed growths in the lines, using an ingenious microscopic technique, and left proof of their skill as scientific observers.

"First there appears a living and growing jelly adhering to surface of pipes, ...; and some months later, spirilla-shaped organisms appear in this jelly. Iron begins to be deposited not on but in this jelly, and ultimately there are long threads in the jelly which acquire a sheath. The sheath thickens by deposition of iron oxide, and the living thread elongates more and more—the sheath following up the thread. A tangled mass results. The older portions become more tangled and dense; and all the time particles are mechanically entangled. Finally, the organism dies at the older end and breaks down, losing its form and becoming a gelatinous flocculent mass of dark ochreous deposit, with the younger sheaths—living threads—growing out of it. Treated with oxalic acid at this stage, the metals are dissolved, and disclose faintly the broken-down and shapeless carbon compounds of disintegrated threads, some of the sheaths occasionally remaining visible."

Reddick and Linderman[115] investigated formation of tubercles in cast-iron pipe to determine causes for their formation and to recommend corrective measures. Their emphasis on biological corrosion was a consequence.

Typical, rather than unusual, pipe fouling is shown in Figure 7. The cleaned lower half of this coupon shows typical pitting found beneath pervious and irregular deposits. The upper half shows a normal conglomeration of metallic oxides; microorganisms; amorphous, colloidal, and crystalline matter that is described as bio-fouling.

L. J. Alexander has presented certain bases for economical evaluation of pipe-line tuberculation.[79]

The water-works profession knows of innumerable cases from New York[74] to San Francisco[78] wherein water systems handling "pure mountain water," treated river waters, or shallow- and deep-well supplies are fouled by accumulated microbiological deposits.

Exactly 30 years elapsed between Campbell Brown's study and the practical application of his knowledge at Utica, New York.[75] A 24-inch cast-iron main 12 miles long, laid in 1906, was in continuous service until 1922, when the value of C in Hazen-Williams formula had fallen to 90, from 109 in 1917, and from 95 in 1921. The main was cleaned in 1922. However, fouling occurred so rapidly that eight cleanings were necessary to meet demands of consumption between 1922 and 1934. Arrangements were made to sterilize and maintain chloramine residuals in all water entering the main. Check determinations show the value of C continues around 130 without evidencing a downward trend, or need for cleaning, since 1934.

When first one western water supply was brought through long tunnels to supply reservoirs, the carrying capacity of an observed line decreased from 16 to 13.6 million gallons per day in a period of a few weeks.[78] On inspection it was found to contain slimy gelatinous growths along with iron bacteria. These growths on the walls ranged in thickness from ⅛ inch to ¼ inch when collapsed after draining. Seeding of the system occurs when there is infiltration of iron bacteria through small cracks in the tunnel walls. For the past several years multiple chlorination of the tunnel system has controlled slime and iron deposits.

Determinations of oxygen depletion in water passing through such tunnels and knowledge of oxygen consumption in normal metabolic processes of similar mixed cultures have been used to calculate that a 3-mile length of 10-foot tunnel contains approximately 19 tons of moist slime. When dried it reduces to 0.23 ton. This difference indicates why the importance

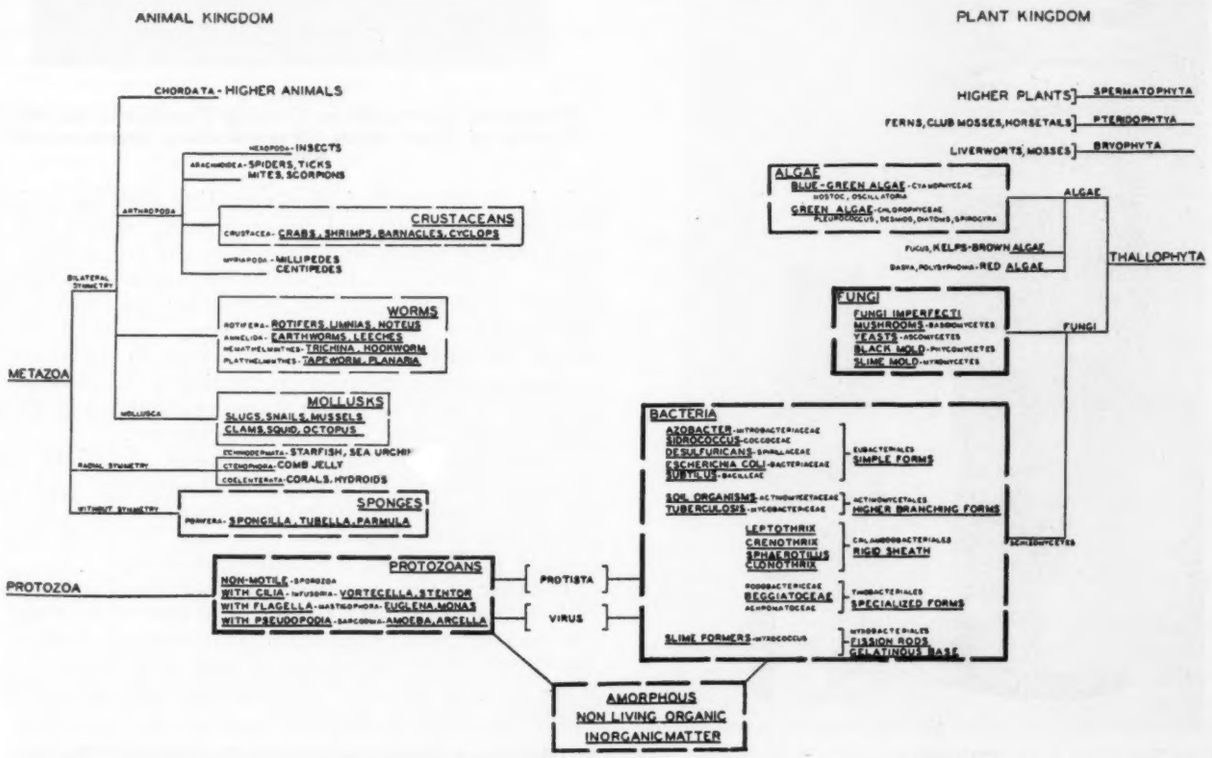


FIGURE 4

Some Common Organisms Associated with Deposits in Water Circuits—Typified Under Weighted Groupings in Rectangles.

of depositions in water systems may be underestimated if considered against dry weights of slime fouling.

Controlled chlorination was specified, and is used to prevent bio-fouling of a 24-inch 10-mile-long supply line to the Freeport Sulphur Company's Grande Ecaille Mines at Port Sulphur, Louisiana, designed to handle deaerated, practically oxygen-free water.

Similarly, microbiological deposits develop in filters, and coat and ball the sand—after which washing becomes difficult or impossible, with consequent reduction in filter runs and increase in backwash costs. Capacity and rate of base exchange in zeolite softeners correspondingly are affected by microbiological deposits.

An early deliberate effort to control microbiological growths in order to eliminate the detrimental results of paper-mill fouling appears to have been made in 1924 at a Michigan mill.[94]

Fouling of Surfaces in Heat-Transfer and Process Units

Rates of growth and consequent deposition in water systems are low in comparison with rates of deposition wherein water and organisms move between temperature zones that differ by increments of 5 to 10° F.

In 1921 Paul A. Bancel[83] was cognizant of the microbiological mechanism underlying slime formation and, further, associated corrosion, scaling, and sliming with respect to their effect upon steam condensation.

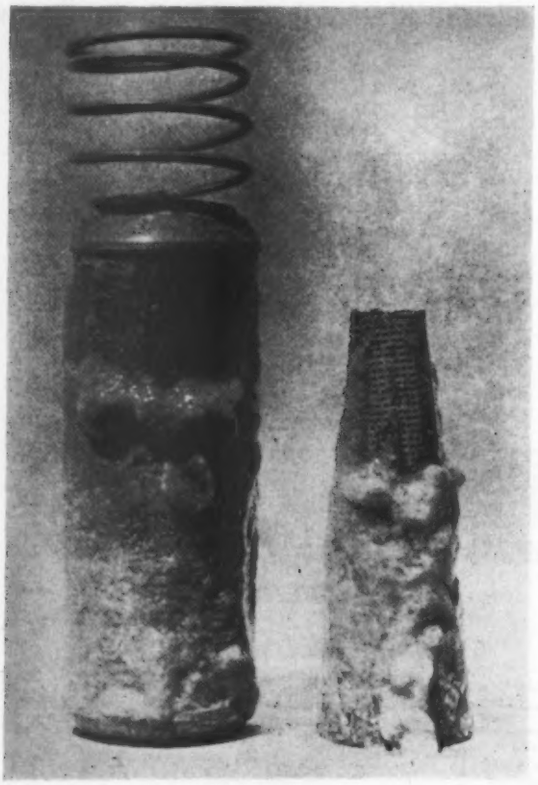


FIGURE 5
A 1941 "Water Calamity"—Sliming of Water Screens (Reduction About One-Third) (Courtesy K. W. Brown).

Bancel states, in part: "The author believes that there are certain causes of corrosion which can be alleviated by the condenser designer. It is widely known from both practical and laboratory experience that heat accelerates corrosion, ... it is also known that corrosion of the local type takes place where foreign matter deposits in the tubes so that keeping the tubes clean, as by the use of higher velocities, will alleviate this form of corrosion."

FIGURE 6
Crenothrix and Spirillum Growing Together in the Bio-Fouling of Water Mains (Magnification, Approximately 400×).

L. L. Robinson[84] of Hackney, England, recognized that the "glutinous and clinging mud," which had "a disagreeable smell" and "assumed the consistency of jelly," obtained its characteristics because of microbiological phenomena. Sir Alexander Houston of the Metropolitan Water Board was consulted, after which Robinson initiated chlorination of central-station surface-condenser circulating water. Robinson prepared a striking graph showing condensing vacua prior to and, then, during chlorination.

Commonwealth Edison Company, Wallace and Tiernan, Electro Bleaching Gas Company, and The Chlorine Institute initiated experimental work in 1924 at the Northwest Station to check American applicability of Robinson's recommendations.[87]

Because of the quantities of water involved in central-station condenser cooling, the cost of continuous chlorination was prohibitive. This led to invention of the intermittent desliming process and its first full-scale test and use at Public Service Electric and Gas Company, Kearny Station.[85]

Relevant Observations on Corrosion Theories

In water works and power-plant practice, economic considerations justify maintenance of clean surfaces; yet in both of these related fields considerable stress can be placed upon the importance of deposit attack and the significance of differential-cell electrolysis. The electrochemical theory of corrosion is so inclusive that most of the logical explanations of results observed can be encompassed within limits of the

theory, except mechanical failures and impingement attack, as common causes of corrosion that need other explanations.

Texts prepared under the direction of Evans,[20] Bengough,[23] Speller,[21] and McKay,[17] which present full analyses of the extensive work on corrosion, are

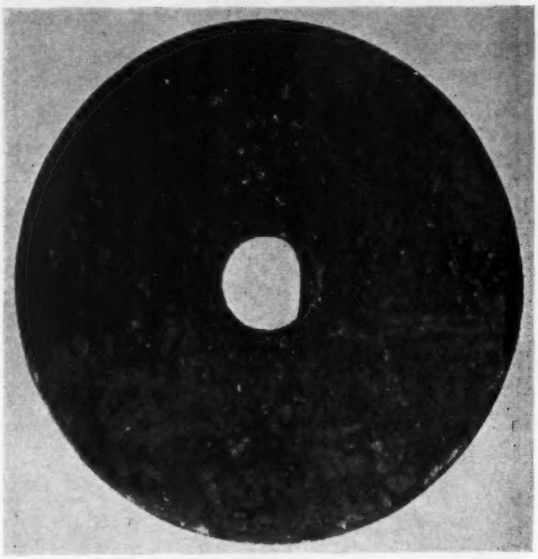


FIGURE 7
Typical Appearance of Mechanically-Cleaned Pipe-Wall Area in Contrast with Normal Deposit Accumulation and Bio-Fouling on Upper Half.

depended upon for the necessary correlated detailed observations herein.

The mechanisms described as operating in differential aeration cells, deposit attack, and direct chemical reaction appear to be most involved in corrosion at zones of microbiological growth. References to differential cells, rather than differential aeration cells, indicate an assumption that oxygen penetration through deposits is not essential to explanations of corrosion in the presence of microorganisms. Consideration of microbiological corrosion can be approached without emphasis upon hydrogen acceptance by, or controversial metabolic aspects of, bacteria, fungi, and algae growth.

Growth of the microorganisms has been associated with corrosion, but in most cases it has not been determined whether electrochemical corrosion results in favorable environmental conditions in which organisms develop and corrosion is accelerated, or whether end products of growth accumulate first and are thus an initial cause. Conversely, it is possible that deposits bound in place by slime-forming organisms can act as protective coatings in special situations.

Development of microbiological depositions on water-system surfaces is objectionable in itself, for the reason that dissimilarity over wetted surfaces undoubtedly establishes differential cells. Microbiological growth in deposits changes the electrolyte beneath and around the deposits. The resulting alteration in the oxidation potential, the pH, the oxygen, the carbon dioxide, the ammonia, the hydrogen sulfide, the iron, the copper, the starch, and the sugar content in the region of deposits is bound to change the character of molecular or oxide films on the metal. Assurance is lacking of protective films being developed to uniform patterns on surfaces which lack uniformity in elemental components, physical-chemical reactions, and general form.

Surface condition of conduits and piping appears to be a more important factor in determining corrosion rates than variations in the composition of any particular alloy.

In addition, Evans, Bengough, May, Speller, and McKay emphasize the importance of:

1. Local accumulation of corrosion products.
2. Settling of foreign substances on tubes.
3. Water speed.
4. Seasonal or other variations in water composition.

The corrosion failures resulting are classified as:

1. "Complete corrosion."
2. "Selective action."

Corrosion of the selective-action type is most difficult to control.

Philo[22] defines deposit attack thusly:

"This type is localized and, therefore, serious. It is connected with deposits in the tube of any foreign material such as a shell, coke, seaweed, or sand, and is usually produced in places where foreign material settles down. It is most common at the inlet and bottom half of the tubes. The corrosion is the result of electrolysis under the influence of local current. The EMF depends on the difference in potential between the surrounding metal and the metal covered with deposit. It might also be that certain corrosion deposits which would otherwise be swept away by the water flow are entrapped by the foreign bodies and sometimes hinder further corrosion. In any case a local current is set up."

Bengough adds the following:

"An isolated obstruction has two other effects on the tube, namely: 1. It may set up an attack on the upstream side of itself; this may occur where the obstruction is too small to affect appreciably the velocity over the cross-section of the tube and when Reynolds turbulence is the main type of flow. 2. It may set up an attack on the downstream side if the obstruction is of sufficient size to constrict notably the water stream and produce violent disturbance; this may result in the impingement of air bubbles on the tube wall on the downstream side of the obstruction."

When surface-condenser chlorination first was discussed, Grunert called attention to considerations by Bengough, May, Evans, and others of the biological theory of corrosion and to accumulations of copper sulfide on slimed condenser-tube surfaces at stations where polluted, nearly oxygen-free water is circulated.

In 1921 Grant, Bate, and Myers[102] made reference to the relationship between microbiological growths and accelerated corrosion as follows: "Finally, the authors wish to point out that . . . . the fermentation products of microorganisms are of serious moment in many other cases of corrosion and fouling."

Summarizing: Bancel, Bate, Myers, Grunert, Bengough, May, Philo, Speller, and the author[116] have called attention to the relationship between selective corrosive action and the presence of microbiological deposits.

All accepted corrosion theories recognize that cases of simple corrosion are limited, and that the usefulness of these theories depends upon a balanced appraisal of environment, locale, and the type of corrosion with respect to the sum total of the physical and chemical factors supporting it. There are no well authenticated cases of failure of water systems or power-plant hydraulic structures solely due to reactions resulting from growth of microorganisms.

Soil Corrosion

The most complete picture of microbiological corrosion develops on pioneer work of Ehrenberg,[51] Cohn,[52] Winogradsky,[53] Molisch,[56] Van Delden,[55]

Harder,[57] Beijerinck,[54] Ellis,[59] von Wolzogen Kuhr,[104] Dorff,[64] Cholodny,[61] Soriano,[65] Cataldi,[65] Waksman,[39] van Neil,[67] Starkey,[66] Ewing,[26] Bunker,[109] Hadley,[106] Bovard,[101] Beckwith,[101] and others.

Dutch and English workers particularly have been

FIGURE 8
A 24-Inch Concrete Sewer After 2 Years. Bacterial Corrosion Concentrated on the Crown and at the Flow Line.

active in pursuing studies of dominant organisms in microbiological deposits.

Fundamental concepts of the mechanism involved were developed in writings of Winogradsky (1888), and Beijerinck (1900).

The von Wolzogen Kuhr[104] work is basic to the presentation by Hadley[105] and Bunker[107] of studies and reports relating growth of sporovibrio desulfuricans (Beijerinck, Starkey) to external corrosion of pipes in boggy soil. von Wolzogen Kuhr's elaboration of the energy concept of the metabolism of sporovibrio desulfuricans is used freely.

Reports of progress in studies of microbiological external pipe corrosion by Hadley and Bunker have led to other observations and considerations of external pipe-line corrision problems, including those of Ganser[110] and Beckwith.[113]

It is questionable whether external corrosion of steel pipes passing through boggy areas results from hydrogen acceptance, or from simple direct chemical reactions between the end products of bacterial growth and pipe metal; or whether this corrosion is explained best by considering it electrochemical corrosion that should be classified with deposit attack.

Hadley[106] calls attention to field precautions—such as removal of supporting blocks, grass, and other cellulose material away from pipes before back-filling—as important in programs of protection against localized corrosion. This indicates a probability of explaining the locality of external pipe corrosion in terms of deposit attack in which microbiological growths are the deposits.

The relation of cellulose as a food supply was noted in 1931, when Bovard and Beckwith[101] studied the disintegration of sulfur-silica joints along a supply main handling relatively warm well waters. Failures occurred in exposed sections of the line carried on trestles, as well as at joints buried in the soil. Sulfur bacteria contaminating the well supply found favor-

FIGURE 9
General Bacterial Corrosion of a 24-Inch Concrete Sewer After 7 Years' Use.

able environmental conditions in the jute packing at a point where a supply of sulfur was available in the joint compound.

Bacterial corrosion of sulfur-silica joint compounds has troubled a water department in Oklahoma, where sections of large-diameter concrete conduit are joined with sulfur-silica compounds. When these joints are constructed in favorable environments, sulfur-silica compound is weakened greatly, and concrete adjacent to joints also is disintegrated by direct reaction of the acid biochemically produced.

Connection between microbiological growth in soil and corrosion of lead sheathing on cables has been established.

The cases of concrete disintegration and sulfur-silica joint corrosion are among the few simple illustrations of direct microbiological corrosion in a mechanism that is not covered necessarily under broad interpretations of accepted electrochemical corrosion theories.

Corrosion of Concrete

Association of concrete failure with hydrogen sulfide was noted in 1897, and well organized studies into this, a form of microbiological corrosion of the Los Angeles Outfall, were reported by Olmstead and Hamlin[97] in 1900 in connection therewith.

Disintegration of concrete appears to be coincidentail with production of hydrogen sulfide under anaerobic conditions in septic sewage, and with growth under anaerobic and aerobic conditions in the moist slimes above the flow line. Sulfur bacteria reduce sulfates in the flow, releasing hydrogen sulfide against the intermittently wetted upper portions of the sewer where the hydrogen sulfide may be oxi-

dized biochemically to sulfurous or sulfuric acid by sulfur-oxidizing organisms, or where it enters an oxidation reaction.

R. F. Goudey[99] reports on failures of concrete structures in El Centro, California, studied during investigations initiated in 1922. Estimates of hydrogen-sulfide production made on the basis of sulfate reductions along the line of sewage flow indicate that more than 600 pounds of hydrogen sulfide are produced from 1 million gallons of sewage. Attempts were made to control the growth of causative organisms by adding copper sulfate and, subsequently, the growths were controlled by chlorination.

Corrosion of concrete results from leaching of the lime component of the cement and its conversion to gypsum, in a process involving formation of the larger gypsum crystal which results in fracture of the mass comparable to rupture by freezing.

This is a clean-cut and one of the obvious cases of progressive bacterial corrosion as a result of the production of metabolic end products that enter into direct chemical reactions with a structural material.

In contrast with the work of von Wolzogen Kuhr, Hadley, and Bunker, investigators of concrete disintegration have not agreed on identity of particular organisms responsible for reduction of sulfates.

Enslow[100] indicates that spirillum desulfuricans are responsible for hydrogen-sulfide production, whereas bacteria of the beggiatoa group and many others in mixed cultures appear to be responsible for subsequent conversion of hydrogen sulfide into sulfuric acid.

DeMartini[81] summarized reports of slime growths in sewers, and listed principal fungi involved.

Corrosion of Copper Tubes

Bancel[83] is one of the first to direct attention to observation of operating personnel regarding effects of deposits on the progress of condenser-tube corrosion.

In general, the authorities hold that corrosion is minimized by use of uniform tubes or by maintaining evenly coated unmarred tubes in service, and they caution against damage during cleaning.

Bengough[23] recommends that careful tube cleaning be practiced primarily to control deposit attack.

> "Attention may be first directed to a rather unpopular palliative for corrosion, namely, tube cleaning, by rodding out with wire brushes, etc. . . . . In no case, however, should coke, clinker, weeds, wood shavings, shells, etc., be allowed to remain in the tubes *against the ferrules,* even if they are not completely choked. Sometimes these substances are held in contact with the ferrules as long as water is passing, and thus set up an attack on them."

In power-plant practice it is reported that surface condensers can be operated for periods of from 4 to 6 months immediately after installation of new tubes, without evidence of sufficient fouling to affect heat transfer beyond an increase of 0.05 inches of mercury in back pressure over the initial period. Once condensers have been fouled and thereafter cleaned, it is noted that from that time on the units foul to the same extent in two to three weeks.

Formation of the copper sulfide on condenser tubes results from anaerobic production of hydrogen sulfide by decomposition of slime films *in situ.* Central-station heat exchangers and condensers that are expected to operate at heat-transfer coefficients between 250 and 800 Btu will not show design performance if tube surfaces are pitted and roughened, or if deposits accumulate on tubes.

Bengough, May, Evans, and Philo pay particular attention to "impingement attack," and present evidence showing that impingement attack develops adjacent to points of deposition of foreign matter. Although deposit attack is related to the porosity of deposits and the effect of deposits upon obvious electrochemical reactions, impingement attack is related to deflection of entrained gas around deposits. In this respect, deposits create turbulent zones in hydraulic systems, and in that way contribute to corrosion. Importance of deposits in respect to production of zones of uneven and sudden temperature change is well established by data pertaining to corrosion and failure of higher-temperature tubes.[30]

Corrosion of Iron Water Channels

The implication that Hill,[69] Campbell, Ellis, and other early workers may have anticipated biological corrosion of iron can be assumed from such descriptions as "spongy disease" of iron, etc.

Alex M. Shanks[103] calls attention to iron and sulfur bacteria on steel hulls of river vessels plying in the Cachr and Bengal districts of India and to the corrosion pattern on these hulls. This work evidently predates that of Reddick and Linderman.

Carl Wilson of Los Angeles has made contemporary observations of the same type of phenomena.

Nature of Microbiological Deposits

Similarly, microbiological growths will produce irregular and objectionable deposits on pipe walls, and in hydraulic structures handling water and wastes in refineries.

Most authorities are in agreement that, in part, corrosion depends upon structural materials used, juxtaposition of changes in materials and surfaces, inhibition of direct chemical reactions, development of protective coatings, elimination of strain, and the nature of sudden changes in temperature and flow

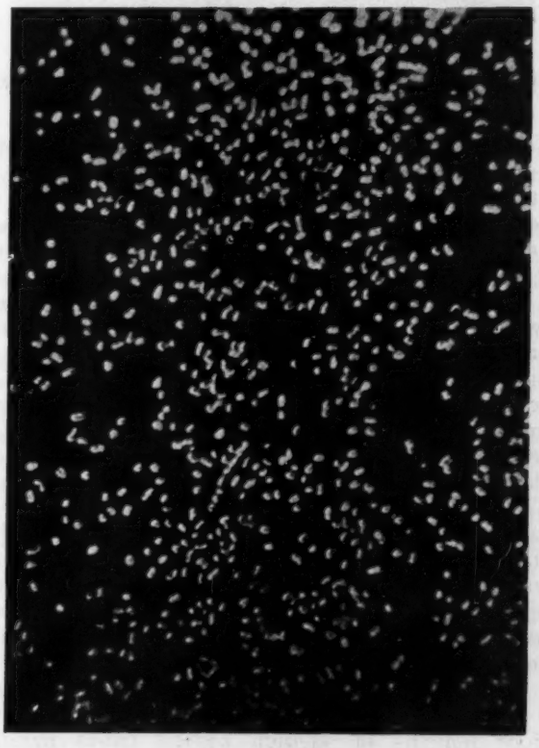


FIGURE 10
Small Slime-Forming Capsulated Coccobacilli (Magnification, Approximately 900×).

velocities. Assuming such an agreement, detailed consideration of the manner in which various physical forms of microbiological accumulation of deposits may alter further the nature of corrosion, heat transfer, and hydraulics in refinery water supply, filtration,

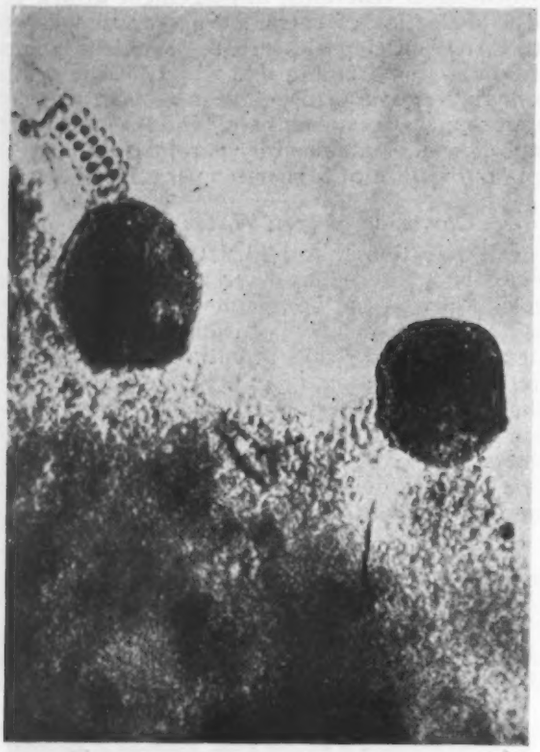


FIGURE 11
Vorticella—Typical of Protozoa in Refinery Water Circuits (Magnification, Approximately 400×).

softening plant, cooling system, and waste-disposal circuits is in order.

Studies of microbiological growths, metabolic end products, and depositions in plant circuits, especially in refineries, are complicated by the irregular pattern and concentration of trouble at inaccessible points and where environmental conditions cannot be altered at will to make possible comparative tests against fixed controls. Until the effects of minor changes in environmental conditions are known, it will be impractical to design and operate pilot units wherein plant-unit conditions for microbiological growth are precisely duplicated during long-term experiments under control and adjustment of critical variables.

To illustrate, tests run to develop empirical, but reliable, rate factors for microbiological growth in surface condensers show that, when portions of polluted river water are passed through tubes, the outside of which are subject to atmospheric temperatures, and when other portions are passed through tubes heated in such a manner that there is a 10°-F. rise in outlet- over inlet-water temperature, at least 100 ml of slime could be removed after 30 days from 20-foot lengths of ¾-inch heated tubes handling water at an inlet temperature of 50° F.; whereas not more than 2 ml or 3 ml of slime-like deposit could be removed from unheated, but otherwise similar, pilot units. Checks of sliming rates, using polluted water over the range from 50 to 85° F. injection temperature, show a constant ratio of fouling for heated vs. unheated tubes, regardless of injection temperatures. Effects of temperature increase in refinery water circuits are important to considerations of microbiological corrosion and deposit formation. Electrochemical corrosion and environmental conditions that tend to sustain the growth of organisms are favored by similar conditions of temperature, rate of motion, oxygen content, mineral composition, and degree of dissociation.

The literature records all manner of analyses as a result of efforts to determine the nature of common tubercular deposits. Hill[69] shows 65 to 90 percent iron oxides, and Campbell 25 to 42 percent iron.

Reddick and Linderman[115] show spreads of from 44 to 69 percent ferric oxide, and several analyses indicating appreciable silica contents.

Philo[22] pays particular attention to organic matter and copper in the green and brown layers of deposits on surface condenser tubes. In particular, the 19 to 25 percent of organic material, together with the 8 to 11 percent silica, is clear evidence that the deposits analyzed are slime residues. Copper and zinc contents of these deposits vary between 7 and 24 percent.

Wallace and Tiernan analyses of slime and scale-like deposits from all types of heat exchangers show 1 or 2 percent organic matter in rare cases, between 15 and 30 percent organic matter when slime is not controlled fully and, occasionally, a sample may show 70 to 80 percent organic material.

The simplest water-circuit deposits are amorphous and zoogleal matter. If, in addition to such a mucilaginous mixture, capsulated bacteria and higher forms of organisms are present and attached to wetted surfaces, the whole will serve to absorb, entrain, and bind organic and inorganic matter carried past the fouled surfaces in the water flow. The mass that results may give the appearance of scale, or it may be nearly pure slime.

In addition, Smith[32] and Welch[31] record that certain bacteria and high-temperature algae in waters wherein carbonates are available are responsible for complex carbonate deposition. This phenomenon is to be observed around hot springs or in lake marls and is, in part, responsible for the coincident coloration. In closed cooling-water systems, wherein mineralized waters are concentrated 5 to 20 times, conditions are so similar that control of microbiological growths can be expected to reduce limited types of scaling.

So far as is known, algae are not of primary importance because of being involved in complicated biochemical carbonate deposition, but are of importance in refineries as organic matter available for agglomeration in slime deposits—whether the deposits are on the surface of heat exchangers or on filters and softeners.

Diatoms contain sufficient silica to be responsible for some silica scaling. Again they accumulate silica from solutions of apparently insignificant concentrations. The rotifera and crustacea are of little or no importance beyond the fact that they contain calcareous and silicious matter. The troubles from bacteria and other fungi in refinery water systems follow from their ability to thrive in the absence of light.

Filiform organisms now are known to grow luxuriantly in water containing dissolved hydrocarbons, and that in this environment they accumulate oil in much the same fashion that crenothrix, leptothrix, and beggiatoa accumulate iron, manganese, and sulfur. So far there is no report of work assembling morphological data nor identifying the organisms in-

volved in the segregation of oil in cooling-water circuits and waste-disposal plants.

In many situations in which sea water is used in refineries, attention should be paid to marine growths described by Zobell and Allen[95] and to the work of van Neil.[67]

Many of the thread-like organisms and other related fungi found in waters from deep wells are classed as crenoform in popular terminology. This classification should not be taken to indicate that all of the related organisms deposit iron, nor that bacteria associated with crenoform growths will obtain oxygen by the reduction of sulfates, sulfites, and thiosulfate without ultimate production of hydrogen sulfide.

In one particular Gulf locality, related thread-like forms have been observed in the well waters, and were reported, in papers of the Geological Survey as early as 1912, as "white algae." The waters in the area do not contain any sulfate, but appear to be contaminated by the diffusion of hydrocarbons similar to mercaptans. When this water is discharged into the distributing system, it appears that the sulfur-containing hydrocarbons are assimilated by microorganisms, with the ultimate production of hydrogen sulfide in a water supply containing an infinitesimal quantity of sulfur compounds. It appears that the organisms assimilate sulfur in their structures and that, following their death, certain complex proteins containing sulfur are made available as food for the remaining bacteria and other fungi—the result of this process being the deposition of a black sludge in the pipe lines that has a characteristic odor noted in the refining of sour crudes. Hydrogen sulfide is in solution in the water in the region of the sludge deposition.

Microbiological growth results in the production of end products normally associated with corrosion phenomena, and the nature of deposits is such that these end products may reach an appreciable degree of concentration. End products *in situ* are available for direct chemical reactions, and provide the necessary conditions for differential-cell corrosion. Some of the important and common end products of biological metabolism are carbon dioxide, hydrogen sulfide, and sulfuric acid. Under aerobic conditions, it is logical to anticipate production of carbon dioxide beneath tubercles containing organisms.

Although all of these related phenomena involve the presence and metabolism of many types of organisms, some authorities tend to limit discussion to the particular significance of certain individual organisms included in the larger groupings.

Microbiological anaerobic activity develops when grossly polluted waters are used for cooling without recirculation over towers. It also appears in the piping of the refinery systems handling wastes, and in the refinery waste-treatment plants. Cellulose, decomposing organisms—which are primarily responsible for sliming and slime accumulation through a series of certain biophysical processes—are, for the most part, capsulated types of bacteria, most of which are unidentified as yet.

Reddick and Linderman were concerned with biochemical reactions under aerobic conditions in systems handling water containing dissolved oxygen. Aerobic organisms develop in refineries, and biochemical reactions under aerobic conditions occur in the fresh water-supply lines, filter and softening plants, cooling-water systems using good quality water, or where the cooling water is aerated in towers. Nearly all the organisms involved in the whole range of water and waste-treatment problems can be observed in any refinery.

Major non-conformities between laboratory work and field conditions occur because of obstacles to the study of pure cultures or limited mixtures, while at the same time subjecting these organisms to environmental influences identical to those obtained under field conditions. Using fresh actively growing organisms, and transferring these from culture to culture, is not reproducing conditions in nature. For example, freshly growing organisms usually produce more than the normal amount of acid. Again, the mechanism of deposit formation and biological corrosion may be, in part, due to the multiple association of a number of organisms, and possibly to symbiotic or other complex relationships that are unknown at this time and would be difficult to reproduce.

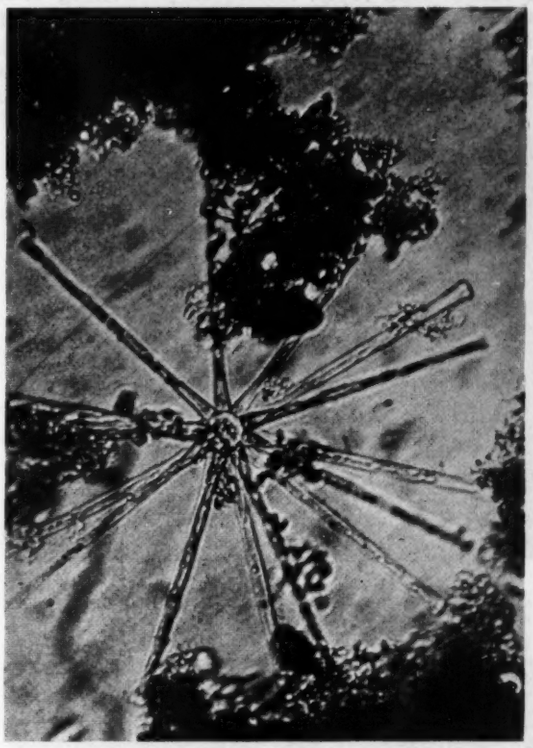


FIGURE 12
Asterionella—One of the Siliceous Diatoms (Magnification, Approximately 400×).

The best information has come from observation of the characteristics of troublesome organisms under field conditions, even though it is all but impossible to control or fix field environmental conditions.

The frank admission that certain phases of biology lack features of more exact sciences makes allowance for broad consideration of theories, showing reasonable promise, without such theories being taken as expressions of fact.

The whole question of microbiological corrosion is controversial, and will remain so until organisms are established firmly either as the primary, or as the secondary, invaders. Growth of organisms is undoubtedly an important factor in the whole water-circuit corrosion picture; therefore, it is logical to conclude that control of microbiological growths, along with other corrective treatments, will be necessary for the complete retardation of corrosion. The study of con-

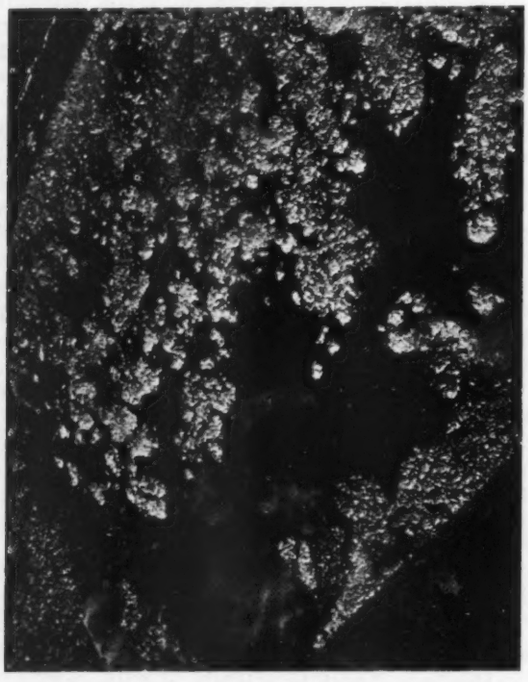
crete corrosion is the all-important assurance that true microbiological corrosion of metals is a real probability, and gives justification for considerable expenditure on organized investigation of the problem.

One promising program of study is being coordinated by L. J. Alexander, chairman of the Committee on Bacterial Corrosion of the Purification Division of the California Section of the American Water Works Association. The committee includes Messrs. Arnold, Backwith, Brown, Goudey, Wilson, and Zobell.

A. Corner of large cooling-water pond, showing typical appearance of biophysical scum formation at various stages—clear water at top.

B. Start of biophysical scum formation and oil accumulation involving microorganisms.

C. First stage—Close view of biophysical scum starting to show oil separation.



D. Second stage—Biophysical scum floc and oil clearly separated.

FIGURE 13

Biophysical Accumulation of Hydrocarbons and Filiform Organisms (Photographs by C. E. Fehrenbach).

Elimination of Bio-fouling of Metal Surfaces

Corrosion control in refinery water circuits reduces to the adjustment of pH, elimination of scaling, prevention of microbiological fouling, maintenance of uniform surfaces, and development of protective coatings. pH adjustment and elimination of scaling call for pretreatment and supplementary internal treatment, or at least controlled blowdown of individual closed circuits.

Competent water-treatment consultants and the established filtration-equipment manufacturers should be brought together with refinery personnel to consider projected solutions of water-conditioning problems. Experience in water treatment is at least as specialized as is experienced in petroleum refining.

The maintenance of uniform surfaces starts with equipment design, and from then on is dependent upon the procedures followed in operating and cleaning practices.

Development of protective coatings may include cathodic protection,[22, 129, 130] surface absorption of

polyphosfates,[125] buildup of chromate,[127] silicate or organic films,[128] controlled deposition of calcium carbonate,[121, 122, 123, 27] and even the application of special paints or lacquers Experience indicates most success in development of protective films or uniform smooth polished surfaces.

It is questionable whether methods for development of protective films can be evaluated without coincidental control of bio-fouling. Of necessity, bacterial growth alters the structure of protective films.

It must be recognized that potable safe water may not be sterile water, and chlorination of many domestic supplies is limited to destruction of, or insuring against, the presence of pathogens. Except in the cases wherein contamination with non-pathogenic fungus forms, and wherein resistant bacteria result in taste production, main fouling, and filter clogging, the average domestic water supply is not sterilized to the point where no microorganisms are to be found in the flow or accumulated in the system.

Similarly, it is not necessary to sterilize completely all water in refinery circuits to control microbiological fouling. It is of prime importance that inhibiting concentrations of chlorine be maintained next to surfaces subject to bio-fouling.

With the exception of certain crustaceans, worms, mollusks, and other higher forms, all organisms known to develop in water circuits can be killed by reasonable concentrations of true residual chlorine. Numbers of slow-growing pleomorphic organisms can survive in solutions of 0.7 ppm to 1.0 ppm residual chlorine, but there is no substantiation for the view that slime-forming organisms develop resistance to chlorine.

E. Third stage—Oil scum predominates; number of organisms greatly reduced and not interlaced in sliming emulsion.

FIGURE 13—*Continued*
Biophysical Accumulation of Hydrocarbons and Filiform Organisms (Photographs by C. E. Fehrenbach).

Quantitative expressions of chlorination, in terms of dosage or ortho-tolidin residuals, do not give, of necessity, accurate information on the true residual chlorine present in all chlorinated aqueous biochemical systems on which the test is used. The ortho-tolidin test for "residual chlorine" is not established for use in controlling chlorination of systems fouled with normally resistant non-pathogenic organisms. Reference to the original basis for standardization of the test is pertinent.[12, 13, 14] Briefly, the standardization is related to empirical proof that satisfactory absence of index of organisms associated with fecal pathogens—and corollary destruction of pathogens—is assured when sufficient chlorine is applied to give specified color reactions—these color reactions having been previously related to the amount of chlorine released when the hydrogen-ion concentration of chlorinated water is adjusted to a pH of 2.0. It does not follow that residual chlorine is present when comparable color reactions are obtained after acidifying portions of water which contain complex biochemical end products, organic matter, and hydrocarbons at the normal pH of operating systems. However, ortho-tolidin standard color reactions of 0.8 ppm to 2.4 ppm, or higher, can be related to concentrations of true residual chlorine required for control of resistant organisms in cooling-water systems (as established by laboratory culture time-of-kill studies).

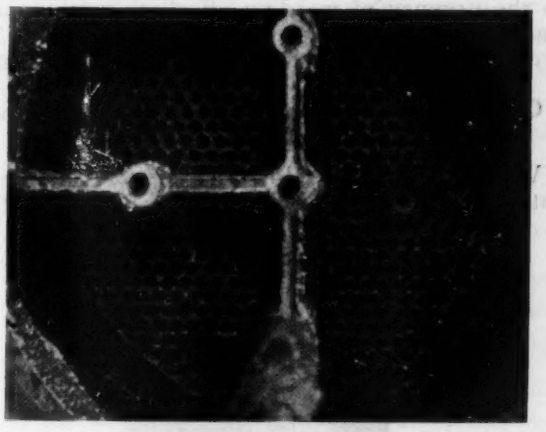


FIGURE 14
Typical Bio-Fouling and Corrosion of Heat-Exchanger Tube Sheet.

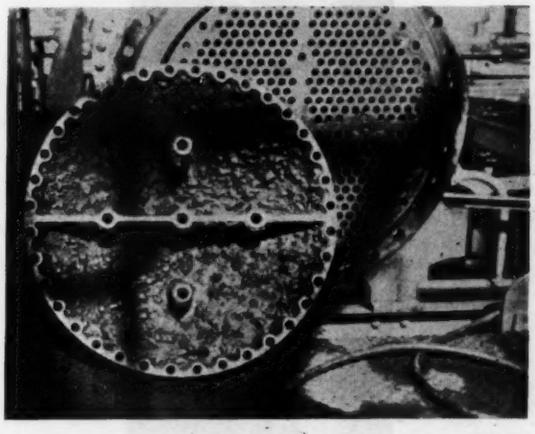


FIGURE 15
Slime-Free Unit—Controlled Chlorination of Cooling Water.

Introduction of sterile water to a system will not effect control of bio-fouling, as these systems have numerous focii of recontamination. Several methods are available for sterilization of water, but chlorina-

tion has the particular advantage of providing sterilization at surfaces where bio-fouling occurs.

Chlorination for protection of domestic water supplies is standardized and reasonably simple. Successful chlorination of polluted cooling, process, and waste-water circuits is dependent on control and regularity of chlorination. If bio-fouling is viewed along with diseases, then the propriety of emphasis on the urgency of warding off sliming is apparent. Once microbiological deposits are developed in a circuit, there results a degree of irreparable damage.

Character of Corrosion-Product Deposits When Scaling and Bio-fouling Are Controlled

When bio-fouling and scaling are controlled, without the subsequent development of protective films,

FIGURE 16

Typical Accumulation of Ferrous Corrosion Products in Regions of High Water Velocities on Clean Surfaces.

normal accumulations of end products of electrochemical corrosion of ferrous metals take characteristic patterns. Figure 14 shows the typical appearance of depositions of corrosion products, scale, and bio-fouling when untreated unchlorinated cooling water is used. Deposits of considerable thickness are scattered all over wetted surfaces.

Figure 15 shows the typical appearance of water-side portions of heat exchangers when filtered softened makeup is provided along with continuous controlled chlorination of cooling water, all recirculated in a circuit where pH concentrations are adjusted and blowdown is programmed with respect to the concentration of solids in the circuit.

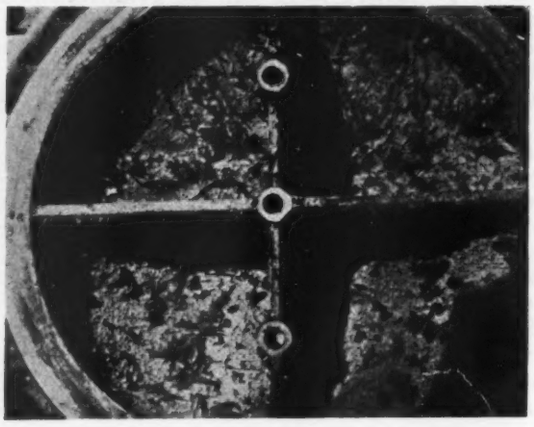
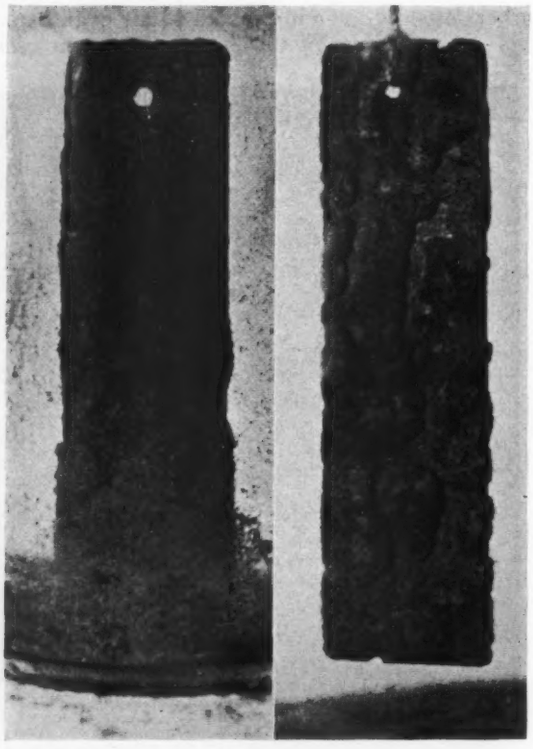


FIGURE 17

A Striking Filamentous Form of Ferrous Corrosion Deposit that Occurs on Clean Surfaces in Regions of Low Water Velocities and without Connection to Microorganic Growths.



A **B**

FIGURE 18

***A.* Bio-fouling of Test Strip in Inoculated Water Corrosion Products Spread and Entrained.**

***B.* Characteristics Deposition of Corrosion Products in Test Strip in Sterile Water.**

(Courtesy M. DeLong.)

Figure 16 shows details of deposit formations under the foregoing conditions when water velocities are high.

Figure 17 shows the characteristic filamentous de-

posits of oxides when water velocities are lower and when there is no biological growth connected with either type of decomposition.

H. L. Fruitman and E. W. Barbee of the San Francisco Water Department (Millbrae Laboratory), have compared the nature of corrosion end-product depositions in seeded and sterile aerated waters—all other factors being held constant. Figure 18-**A** shows a corroded test strip suspended in the inoculated water, and Figure 18-**B** shows the test strip with the type of corrosion deposits developed in sterile aerated water.

Specimen weight losses after removal of the deposits were identical, within limits of experimental error.

Actual Practice

Practical control of bio-fouling is widespread. To illustrate, Wallace and Tiernan equipment, having a total chlorine capacity of 30,000 pounds per 24 hours, is installed on refinery cooling-water circuits. Through this equipment 3,700 to 6,000 pounds of chlorine is used daily to control bio-fouling in systems with a total recirculating rate of 1,100,000,000 gallons of water per day.

A total chlorinator capacity of 250,000 pounds per 24 hours is installed at central generating stations and industrial plants where cooling waters are not recirculated. Approximately 30,000 to 50,000 pounds of chlorine is applied daily to the corresponding 17,000,000,000 gallons of water used.

Control of bio-fouling in refineries was pioneered in 1926 at the same refinery where biophysical accumulation of silica in boilers was reduced, and where zeolite softener operation first was improved by chlorination of the deep-well supply which "destroys the organism which had caused a serious slime growth throughout the distribution system."[82]

This original work led to a complete layout of makeup and cooling-water treatment at the Shell Chemical Company alcohol plant at Dominguez. L. L. Carter was responsible for meticulous design of makeup and cooling-water treatment units that are used to soften and rechlorinate domestic-quality water supplied by the local utility company. J. G. Carriere has directed particular attention to the operation of the water-treatment plant—with the result that heat exchangers have been in continuous service since 1936 without having been removed from service on account of fouling; neither have they been cleaned on the water side during other shutdowns. Admiralty and other alloy tubes continue to have the bright polished appearance of a gun barrel, and original heat-transfer coefficients have been maintained.

Summary

The bio-fouling of refinery water circuits is a factor in corrosion of structural materials. The mechanics of bio-fouling are well understood, and means for complete control are available. Successful control of fouling is predicated, by agreement, on the need for careful and systematic attention to control, provision of adequate equipment, and use of sufficient dosages. The needs are identical to those recognized necessary to the control of diseases and pests.

Control of bio-fouling, pretreatment, internal treatment, and the development of protective films are inseparably connected in complete efforts to effect corrosion control. Each by itself is valuable, but the maintenance of unfouled surfaces in water circuits depends on combined use of all.

ACKNOWLEDGMENT

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BIBLIOGRAPHY

(References to detailed or special work follow the notations of general or basic texts and articles.)

A. GENERAL—WATER TREATMENT AND SEWAGE DISPOSAL

[1] *Manual of Water Quality and Treatment,* 1st edn., American Water Works Assoc., New York (1940).
[2] *American Water Works Association Manual of Water-Works Practice,* Williams and Wilkins Co., Baltimore (1929).
[3] J. W. Ellms, *Water Purification,* 2nd edn., McGraw-Hill Book Co., New York (1928).
[4] L. Pearse (editor), *Modern Sewage Disposal,* Federation of Sewage Works Assoc., New York (1938).
[5] C. E. Keefer, *Sewage Treatment Works—Administration and Operation,* 1st end., McGraw-Hill Book Co. (1940).
[6] K. Imhoff and G. M. Fair, *Sewage Treatment,* John Wiley and Sons, New York (1940).
[7] F. E. Hale, *The Use of Copper Sulfate in Control of Microscopic Organisms,* Nichols Copper Co., New York (1937).
[8] J. Race, *Chlorination of Water,* John Wiley and Sons, New York (1918).
[9] *Chlorination in Sewage Treatment,* Report of the Committee on Sewage Disposal—Public Health Engineering Section, American Public Health Assoc. (1934).
[10] L. H. Enslow, "Discussion of Papers Dealing with Chlorination," *J. Am. Water Works Assoc.* **26** [11] 1667-9 (1934).
[11] J. W. Ellms and S. J. Hauser, "Ortho-tolidin as a Reagent for the Chlorimetric Estimation of Small Quantities of Free Chlorine," *J. Ind. Eng. Chem.* **5** [11] 915 and 1030 (1913).
[12] A. Wolman and L. H. Enslow, "Chlorine Absorption and the Chlorination of Water," *J. Ind. Eng. Chem.* **11** [3] 209 (1919).
[13] H. F. Muer and F. E. Hale, "Readjustment of Present Orthotolidin Standards for Chlorine," *J. Am. Water Works Assoc.* **13** [1] 50 (1925).
[14] M. L. Koskin, "Dosage of Chlorine in Ammonia—Chlorine Treatment of Water," *J. Am. Water Works Assoc.* **29** [11] 1761-74 (1937).
[15] F. C. Schmelkes, "The Oxidation-Potential Concept of Chlorination," *J. Am. Water Works Assoc.* **25** [5] 695-703 (1933).
[16] R. D. Pomeroy, "Oxidation-Potential Theory Applied to Sewage," *Calif. Sewage Works J.* **6** [2] 43-9 (1934).

B. CORROSION—GENERAL THEORY AND EXPERIENCE

[17] R. J. McKay and R. Worthington, *Corrosion Resistance of Metals and Alloys,* Reinhold Publishing Corp., New York (1936).
[18] J. C. Hudson, *Corrosion of Iron and Steel,* Chapman and Hall, Ltd., London (1940).
[19] R. Baylis, "Causes, Effect, and Elimination of Corrosion," *Sixth Annual Report of the Missouri Water and Sewerage Conference* **2** [6] Oct. (1930).
[20] U. R. Evans, *Metallic Corrosion Passivity and Protection,* Edward Arnold and Co., London (1938).
[21] F. N. Speller, *Corrosion—Causes and Prevention,* 2nd edn., McGraw-Hill Book Co. (1935).
[22] F. G. Philo, "Electrolytic Corrosion Prevention of Condenser-Tube Corrosives," *J. Am. Water Works Assoc.* **20** [6] 505-534 (1928).
[23] G. D. Bengough and R. May, "Seventh Report to the Corrosion Research Committee of the Institute of Metals," *J. Inst. Metals* **32,** 81-269 (1924).
[24] R. May, "Eighth Report to the Corrosion Research Committee of the Institute of Metals," *J. Inst. Metals* **40** *part* **2,** 141-85 (1928).
[25] A. E. Pew, "Corrosion Problems Affecting Oil Vapor Condensers, *Refiner Natural Gasoline Mfr.* **10** [5] 79-87 (1931).
[25a] R. D. Pomeroy, "Corrosion of Iron by Septic Sewage," presented at spring conference, California Sewage Works Assoc., Apr. 22, at Santa Cruz, Calif.; to be published in *Calif. Sewage Works J.* (1941).
[26] S. Ewing, *Soil Corrosion and Pipe-Line Protection,* American Gas Assoc., New York (1938).
[27] *Bibliography on Deterioration of Condensing Equipment (Am. Soc. Mech. Engrs. Research Publication),* American Society of Mechanical Engineers, New York (1931).
[28] R. A. Wilkins, E. S. Bunn, and W. Lynes, "Corrosion of Copper and Copper-Base Tubing in Oil-Refinery Heat-Transfer Equipment," *Proc. API* **21M** [III] 46 (1940).
[29] *Condensing Equipment,* Serial Report of Prime-Movers Committee, Engineering National Section, National Electric Light Assoc., Jan. (1927).
[30] R. E. Hall, *A Physicochemical Study of Scale Formation and Boiler-Water Conditioning,* Carnegie Institute of Technology, Pittsburgh (1927).

C. GENERAL MICROBIOLOGY

[31] P. S. Welch, *Limnology,* McGraw-Hill Book Co. (1935).
[32] G. M. Smith, *Fresh-Water Algae,* 1st edn., McGraw-Hill Book Co. (1933).
[33] H. B. Ward and G. C. Whipple, *Fresh-Water Biology,* John Wiley and Sons (1918).
[34] R. Kirkpatrick, *The Biology of Water Works,* British Museum (Natural History), Economic Series No. 7, 3rd edn. (1924).
[35] G. C. Whipple, G. M. Fair, and M. C. Whipple, *Microscopy of Drinking Water,* 4th edn., John Wiley and Sons (1927).
[36] A. J. Salle, *Fundamental Principles of Bacteriology,* McGraw-Hill Book Co. (1939).
[37] H. Zinsser, P. H. Hiss, and Bayne-Jones, *A Textbook of Bacteriology,* 7th edn., D. Appleton-Century Co., New York (1935).
[38] R. E. Buchanan and E. S. Fulmer, *Physiology and Biochemistry of Bacteria* **II and III,** Williams and Wilkins Co. (1930).
[39] S. A. Waksman, *Principles of Soil Microbiology,* 2nd edn., Williams and Wilkins Co. (1932).
[40] Prescott and Winslow, *Elements of Water Bacteriology,* John Wiley and Sons (1915).
[41] M. Stephenson, *Bacteriological Metabolism,* Longmans, Green and Co., London (1939).
[42] B. Hampil, "The Influence of Temperature on the Life Processes and Death of Bacteria," *Quart. Rev. Biol.* **7** [2] 172-96 (1932).
[43] A. J. Kluyver, *The Chemical Activities of Microorganisms,* University of London Press (1931).
[44] E. R. Quortrop and A. L. Holt, "Detection of Potential Botulinus Toxin Production Area in Western Duck Marsh with Suggestions for

Control," Wild Life Research, U. S. Fish and Wild Life Service, Dept. Interior, *J. Bact.* **41** [3] 363-72 (1941).
[45] Ray L. Derby, "Bacteriology in Relation to Sewage Disposal," *Calif. Sewage Works J.* **10** [1] 37-43 (1938).
[46] D. H. Bergey, *Manual of Determinative Bacteriology,* 3rd edn., Williams and Wilkins Co. (1930).
[47] L. F. Hewitt, *Oxidation-Reduction Potentials in Bacteriology and Biochemistry,* London County Council, Mar. (1936).
[48] E. A. Bessey, *A Textbook of Mycology,* P. Blakiston's Son and Co., Philadelphia (1939).
[49] R. W. Thatcher, *The Chemistry of Plant Life,* McGraw-Hill Book Co. (1924).
[50] H. S. Pratt, *Manual of the Common Invertebrate Animals,* A. C. McClurg and Co., Chicago (1925).

D. IRON AND SULFUR BACTERIA

[51] C. G. Ehrenberg, "Vorläufige Mitteilungen über das wirkliche Vollkommen fossiler Infusorien und ihre grosse Verbreitung," *Poggendorfs Ann.* **38,** 213-27 (1836).
[52] F. Cohn, "Ueber den Brunnenfaden (Crenothrix polyspora) mit Bemerkungen über die mikroskopische Analyse des Brunnenwassers," *Beitr. Biol. Pflanzen* **1** [1] 108-131 (1875).
[53] S. Winogradsky, "Ueber Eisenbakterien," *Botan. Zeitung* **46,** 262-70 (1888).
[54] M. W. Beijerinck, "Ueber Spirillum Desulfuricans als Ursache von Sulfatreduktion," *Centr. Bakt. Parasitenk* [II] **1,** 1 (1895).
[55] A. Van Delden, "Beitrag zur Kenntnis der Sulfatreduktion durch Bakterien," *Centr. Bakt.* **II** [11] 81 (1904).
[56] H. Molisch, *Die Eisenbakterien,* Jena (1910).
[57] E. C. Harder, "Iron-depositing Bacteria and their Geologic Relations," *U. S. Geol. Survey Professional Paper No. 113* (1919).
[58] D. Ellis, *Iron Bacteria,* Frederick A. Stokes Co., New York (1919).
[59] D. Ellis, *Sulfur Bacteria,* Longmans, Green and Co., London-New York (1932).
[60] J. K. Baars, "Ober Sulfaatreductie door Bacterien," Dissertation, Delft (1936).
[61] N. Cholodny, "Die Eisenbakterien—Beitrage zu einer Monographie," Pflanzenforschung, herausgegeben von Prof. Dr. R. Kolkwitz, Berlin-Dahlem (1926).
[62] E. S. Bastin, F. E. Greer, C. A. Merritt, and M. Gail, "The Presence of Sulfate-reducing Bacteria in Oil-Field Waters," *Science News Service* **63** [1518] 21-4 (1926).
[63] K. W. Brown, "The Occurrence and Control of Iron Bacteria in Water Supplies," *J. Am. Water Works Assoc.* **26** [11] 1684-1700 (1934).
[64] P. Dorff, "Die Eisenorganismen—Systematik und Morphologie," Pflanzenforschung, herausgegeben von Prof. Dr. R. Kolkwitz, Berlin-Dahlem (1934).
[65] M. S. Cataldi, "La presencia de bacterias del hierro en las aquas de consumo de la ciudad de Buenos Aires," *Bol. de Obras Sanitarias de la Nacion,* Nov. (1937).
[66] R. L. Starkey, "A Study of Spore Formation and Other Morphological Characteristics of Vibro Desulfuricans," *Arch. Mikrobiol.* **9** [3] 268 (1938).
[67] C. B. van Niel, "On the Morphology and Physiology of the Purple and Green Sulfur Bacteria," *Arch. Mikrobiol.* **3** [1] (1931).

E. MICROBIOLOGICAL FOULING

[68] J. C. Brown, "Deposits in Pipes and Other Channels Conveying Potable Water," *Circ. Eng. Proc.* **156,** Sess. 1903-4, part 2, 1-17 (1940).
[69] N. S. Hill, Jr., "Tuberculation and the Flow of Water in Pipes," *J. Am. Water Works Assoc.,* 303 (1907).
[70] C. A. H. von Wolzogen Kuhr, "Manganese in Water Works," *J. Am. Water Works Assoc.* **18** [1] 1 (1926).
[72] A. Goffey, "Treating Water to Prevent Ferruginous Encrustations," *Public Works* **62** [6] 32 (1931).
[73] F. W. Hammond, "Action of Bacteria in the Tuberculation of Water Mains," *Water Works and Sewerage* **79** [12] 415 (1932).
[73] G. C. Hodges and J. W. Ackerman, "Maintaining Carrying Capacity of Cast-Iron Main by Introduction of Chloramines," *J. Am. Water Works Assoc.* **27** [1] 86-90 (1935).
[74] F. E. Hale, "Manganese in the Croton Water of New York City," *J. Am. Water Works Assoc.* **20** [11] 661 (1928).
[75] J. W. Ackerman, "Checking Tuberculation by Chloramine Treatment," *Water Works and Sewerage* **85** [4] 424 (1938).
[76] F. E. Hale, "Manganese Dioxide in the Aqueduct of the Catskill Water Supply," *J. Am. Water Works Assoc.* **22** [4] 462 (1930)
[77] T. R. McCrea, "Removal of Organic Bound Iron from Highly Colored Water," *J. Am. Water Works Assoc.* **25** [7] 931-46 (1933).
[78] G. E. Arnold, "Crenothrix Chokes Conduits," *Eng. News-Record* **116** [22] 774-5 (1936).
[79] L. J. Alexander, "Economic Evaluation of Tuberculation in Pipe Lines," *J. Am. Water Works Assoc.* **32** [3] 371-86 (1940).
[80] A. M. Buswell and Max Suter, "A Study of Floc-forming Organisms in Chlorinated Water Supplies," *J. Bact.* **3** [5] 583-7 (1934).
[82] F. E. DeMartini, "Slime Growth in Sewers," *Sewage Works J.* **6** [5] 950-5 (1934).
[85] G. T. Luippold, "The Use of Liquid Chlorine in Southern California for Purification and Sanitation," *Hydraulic Eng.,* Nov. (1929).
[88] Paul A. Bancel, "Steam-condensing Plants," *Am. Soc. Mech. Engrs. Pub. No. 1819* (1921).
[84] L. L. Robinson, "Chemical Treatment of Condensing Water for the Prevention of Algoid and Similar Fouling of Condenser Tubes," *Elec. Times,* June 22 (1922).
[85] V. M. Frost and W. F. Rippe, "Experience in Chlorinating Condenser Circulating Water," presented at Metropolitan Section, American Society Mechanical Engineers (Nov. 21, 1929), *Wallace and Tiernan Tech. Pub. No. 112* (1929).
[86] "Chlorination of Circulating Water," Report on Power-Station Chemistry of the Prime-Movers Committee and Operating Committee of Edison Electric Institute (1932-1933).
[87] "Chlorination of Circulating Water." Report on Condensing Equipment of the Prime-Movers Committee, Engineering National Section, National Electric Light Assoc., *Wallace and Tiernan Tech Reprint* (1929-1930).
[88] R. B. Martin, "Chlorination of Condenser Cooling Water," *Trans. Am. Soc. Mech. Engrs., Paper FSP-60-16,* 475-83; *Wallace and Tiernan Tech. Reprint No. 468* (1938).
[89] N. C. Estes, "Chlorination of Cooling Waters," *Refiner & Natural Gasoline Mfr.* **17** [5] 191 (1938).
[90] D. V. Onslow, "The Prevention of Trouble Due to Aquatic Growths in Condenser Systems," *World Power* **12** [76] 379-81 (1930).
[91] S. T. Powell, "Slime and Mussel Control in Surface Condensers and Circulating-Water Tunnels," *Combustion,* 7-13, Apr. (1933).
[92] B. E. Doll, D. W. Graham, and R. F. Goudey, "Final Report—Analyses of Los Angeles Harbor Water for Proposed Steam Plant," Los Angeles Department of Water and Power, Bureau of Water Works and Supply, Sanitary Engineering Division to Bureau of Power and Light, Design and Construction Division (unpublished report) Jan. 1 (1940).
[93] C. M. Baker, *Slime Control,* American Paper and Pulp Assoc., New York, Feb. (1932).
[94] R. B. Martin and A. E. Griffin, "Microbiological Control in Pulp and Paper Manufacturing," presented at Twenty-fifth Annual Meeting of the Technical Assoc. of the American Pulp and Paper Industries, New York, *Wallace and Tiernan Tech. Reprint No. 472* (1940).
[95] C. E. Zobell and E. C. Allen, "The Significance of Marine Bacteria in the Fouling of Submerged Surfaces," Scripps Institution of Oceanography of the University of California, La Jolla, Calif., July (1934).
[96] W. Davendamm, "The Possible Role of Microorganisms in the Precipitation of Calcium Carbonate in Tropical Seas," *Science* **73** [1900] 597-8 (1931).

F. MICROBIOLOGICAL CORROSION

[97] F. H. Olmsted and H. Hamlin, "Converting Portions of the Los Angeles Outfall Sewer into a Septic Tank," *Eng. News* **44** [19] 317-8 (1900).
[98] R. E. Buchanan and W. M. Barr, "Production of Excessive Hydrogen Sulfide in Sewage-Disposal Plants and Consequent Disintegration of the Concrete," *Iowa Eng. Exp. Sta. Bull. No. 26* (1912); and *J. Ind. Eng. Chem.* **4** [8] 564 (1912).
[99] R. F. Goudey, "Outfall Sewer Experiences in Imperial Valley," *Eng. News-Record* **98** [16] 648-9 (1927).
[100] L. H. Enslow, "The Use of Chlorine for Preventing Disintegration of Sewers," Report of Fifth Oklahoma Water Works Short Course, May (1929).
[101] T. D. Beckwith and P. F. Bovard, "Bacterial Disintegration of Sulfur-containing Sealing Compound in Pipe Joints," *Univ. Calif. Pub., Bull. Dept. Geol. Sci.* **1** [7] 121-32 (1937).
[102] R. Grant. E. Bate, and W. H. Myers, "Influence of Fermentation Products of Bacteria on Corrosion in Condensers," *Inst. Engrs., Australia, Sydney Div., Paper 8* (1921).
[103] A. M. Shanks, "Iron and Sulfur Bacteria and Corrosion," *Indian & Eastern Engr.,* 570-72, May (1931).
[104] C. A. H. von Wolzogen Kuhr, "De sulfaatreductie als corzaak der aantasting van ijzeren buisleidingen" ("Sulfate Reduction as the Cause of the Corrosion of Iron Pipe Lines"), *Wasser u Gas* **VII** [26] 277 (1923).
[105] R. F. Hadley, "Microbiological Anaerobic Corrosion," *Oil Gas J.* **38** [19] 92 (1939).
[106] R. F. Hadley, "Studies in Microbiological Anaerobic Corrosion," American Gas Assoc., New York (Publication, Technical Section) (1940).
[107] H. J. Bunker, "The Role of the Sulfate-reducing Bacteria in Metallic Corrosion," *Proc. Brit. Assoc. Refrig.* **33** [1] 151 (1936-7).
[108] H. J. Bunker, "Microbiological Experiments in Anaerobic Corrosion," *J. Soc. Chem. Ind.* **58** [3] 93-100 (1939).
[109] H. J. Bunker, "Microbiological Anaerobic Corrosion," *Chemistry and Industry* **24** [59] 412-4 (1940).
[110] P. Ganser, "Pipe-Line Corrosion Caused by Anaerobic Bacteria," *Gas Age* **86,** 25-6 and 40, July 18 (1940).
[111] C. A. H. von Wolzogen Kuhr and L. S. Van Der Vlugt, "The Graphitization of Cast Iron as an Electrobiochemical Process in Anaerobic Soils," *Water* [16] 147 Aug. 3 (1934).
[112] C. A. H. von Wolzogen Kuhr, "The Corrosion of Lead and Copper Water Pipes in the Ground," *Water* [25] Dec. 15 (1939).
[113] T. D. Beckwith, "Bacterial Corrosion of Iron and Steel," *J. Am. Water Works Assoc.* **33** [1] 147-67 (1941).
[114] H. A. Knudsen, "Corrosion and Tuberculation," *J. Am. Water Works Assoc.* **32** [3] 387-93 (1940).
[115] H. G. Reddick and S. E. Linderman, "Tuberculation of Mains as Affected by Bacteria," *J. New Engl. Water Works Assoc.* **46** [2] 146-69 (1932).
[116] W. J. O'Connell, Jr., "Condenser-Water Chlorination," a report of Wallace and Tiernan Products, Inc., to Brooklyn Edison Co. on surface condenser-water chlorination; private communication to D. C. Weeks, Nov. (1930).

G. CORROSION CONTROL

[117] J. R. Baylis, "Treatment of Water to Prevent Corrosion," *J. Am. Water Works Assoc.* **27** [2] 220-34 (1935).
[118] S. T. Powell, "Corrosion in Steam Generating Stations and its Correction," *Combustion,* 14-18, Jan. (1934).
[119] V. V. Kendall and F. N. Speller, "Recent Developments in Corrosion Prevention of Ferrous Metals," *Ind. Eng. Chem.* **23** [7] 735-42 (1931).
[120] A. Wolman, "Controlling Corrosion of Distribution Systems," *J. Am. Water Works Assoc.* **25** [7] 947 (1933).
[121] W. F. Langelier, "The Analytical Control of Anti-corrosion Water," *J. Am. Water Works Assoc.* **28** [10] 1500 (1936).
[122] F. E. DeMartini, "Corrosion and the Langelier Calcium-Carbonate Saturation Index," *J. Am. Water Works Assoc.* **30** [1] 85-111 (1938).
[123] C. P. Hoover, "Practical Application of Langelier Method," *J. Am. Water Works Assoc.* **30** [11] 1802-7 (1938).
[124] "Symposium: Corrosion Control," *J. Am. Water Works Assoc.* **30** [8] 1342-87 (1938); **33** [2] 286-314 (1941).
[125] O. Rice and G. B. Hatch, "Threshold Treatment of Municipal Water Supplies," *J. Am. Water Works Assoc.* **31** [7] 1171-85 (1939).
[126] G. B. Hatch and O. Rice, "Corrosion Control with Threshold Treatment," *Ind. Eng. Chem.* **32** [12] 1572 (1940).
[127] W. R. Finney and H. W. Young, "Scale and Corrosion Problems in Gasoline Plants," *Petroleum World* **12** [1] 112, 114, 138, (1927).
[128] D. W. Haering, "Scale and Corrosion Control in Aqueous Systems," *Water Works and Sewerage* **83** [8] 275-8 (1936).
[129] J. A. Jamison, "Corrosion Protection of Refinery Equipment," *Proc. API* **19** [III] 46-89 (1938).
[130] E. Cumberland, "The Electrolytic Method of Preventing Corrosion," *J. Inst. Metals* **15,** 192-202 (1916).
[131] L. G. Vande Bogart, "Combating Corrosion in Industrial Process Piping," *Techn. Paper No. 408,* Crane Co., Chicago, May (1939).
[132] E. Larson, "Pipe Corrosion and Coatings," *Am. Gas J.* **148** [2] 18 (1938).

Cathodic Protection

Of Open-Tank Condensers

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CATHODIC protection as a means of combating corrosion is not new, but a comparatively small amount of data is available on its application to open-tank condensers.

The same general principles of cathodic protection which have been applied widely and successfully to pipe lines apply equally well to the protection of open-tank condensers.

The performance records of installations in open-tank condensers are meager, but they all indicate positive benefits.

The installation and operating costs are relatively low in comparison with the possible savings through reduction of corrosion, particularly in severe cases.

There is need, however, for further development work to determine the economic justification for cathodic protection in cases of moderate corrosion.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

CATHODIC protection as a means of combating corrosion of metallic structures in contact with water has been familiar to us for a long time. It has been applied for years to ships' bottoms, submerged and under-ground cables and pipe lines, and in a few instances to shell-and-tube type condensers or coolers. Some of the installations have used zinc plates as anodes, depending upon galvanic action between the anodes and the structure to be protected, which structure acts as a cathode. The remainder have used external sources of potentials to produce the protective current.

Cathodic protection of some types of equipment, notably pipe lines, has produced incontestable beneficial results, and a good deal of valuable data has been recorded. So far, however, we have not been able to discover any published information of a strictly technical nature on cathodic protection of open-tank condensers. Several people have made successful installations, but apparently no one has attempted to collect and coordinate the data available from these various sources.

Undoubtedly other individuals aside from those with whose work the author is familiar also have made studies of this subject, and possibly have made actual installations. It is hoped that this paper will bring comments from them, which will constitute valuable additions to the data which we now have.

Present Status of Cathodic Protection As Applied to Open-Tank Condensers

With this introduction we should like to review the present status of cathodic protection of open-tank condensers by citing the service record of the installations of which we have records, as follows:

1. Naph-Sol Refining Company at Muskegon, Michigan, has had an installation in service in its 6000-square-foot distillate condenser box since late 1938. Prior to that date corrosion of the coils had been severe, necessitating replacement of the entire coils twice, at intervals of approximately eight to nine months, although during this period a set of zinc plates provided a galvanic-cell protection which was of only small benefit. The cathodic-protection system installed in 1938 involved the use of a small motor generator delivering about 10 amperes. The present set of coils in the tank was installed about three months prior to the placing in operation of the motor generator, and these coils are still in good condition after almost 2½ years of service.

Two additional coils, however, were installed several months ago at either end of the box, and these have corroded. Therefore, within the past few weeks, the anodes have been replaced by others of larger area and better distribution, and the intention is to purchase a rectifier of larger current capacity than the present motor generator.

2. Richfield Oil Corporation at Wilmington, California, has had several installations operating successfully for about two years on its new 50,000-barrel plant. Walton C. Poole, of Sinclair Refining Company, at East Chicago, Indiana, has furnished us with the following data regarding these installations.

Corrosion developed very rapidly when this plant was started up, and leaks developed within three months. Cathodic-protection equipment then was installed on all the condenser and cooler boxes of this plant, and no further trouble from corrosion has been encountered.

The benefits of cathodic protection have been confirmed here through the installation of test samples. The test samples consist of small plates of the same material as the condenser tubes. They are located in the condenser in pairs, one of each pair being connected solidly to the tube so as to receive the benefit of the protection, and the other being insulated from the tube so as to be without protection. Considerably less corrosion has occurred on the protected samples than on the insulated samples.

It was observed further that, as a result of the cathodic protection, the precipitate deposited from the water onto the condenser tubes was of a soft nature, and could be hosed off when the plant was shut down and the tank drained; whereas, without protection, the deposit was in the form of a hard scale. This feature was well demonstrated on one occasion when one of these units was taken out of service because of a short circuit which developed in it, and the plant run was completed without this unit in operation. When the plant next was brought down for cleaning, this box was found to be badly scaled up.

It was found also that cathodic protection ap-

peared to result in better heat transmission through elimination of hard-scale formation on the condenser tubes.

3. Sinclair Refining Company at East Chicago has installed an experimental unit constructed similar to those in successful operation at the Richfield plant. The total area of cathodes in this condenser, i.e., the tank and coils combined, is approximately

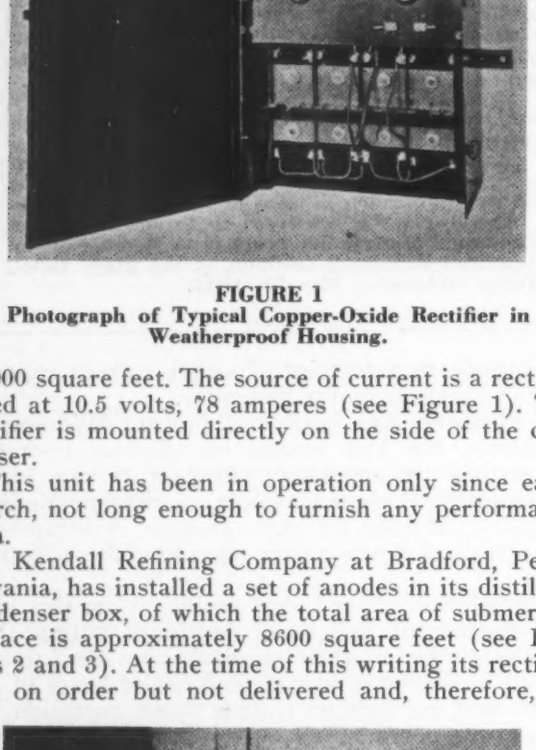


FIGURE 1
Photograph of Typical Copper-Oxide Rectifier in Weatherproof Housing.

25,000 square feet. The source of current is a rectifier rated at 10.5 volts, 78 amperes (see Figure 1). The rectifier is mounted directly on the side of the condenser.

This unit has been in operation only since early March, not long enough to furnish any performance data.

4. Kendall Refining Company at Bradford, Pennsylvania, has installed a set of anodes in its distillate condenser box, of which the total area of submerged surface is approximately 8600 square feet (see Figures 2 and 3). At the time of this writing its rectifier was on order but not delivered and, therefore, no

FIGURE 2
Photograph of Installation of Anodes at Kendall Refining Company.

operating data are yet available from this unit.

We should like to quote from a letter which we received about a year ago from Kendall setting forth the reasons which prompted them to make this installation:

"We figure that our condenser-coil cost, for 1931 up to 1939, was approximately $10,500, representing the cost of the original coils and the replacement of the top section on two different occasions. Then in 1939 a complete replacement was made, the cost of which was approximately $7200. You can see from this that any protection which will decrease this cost, which is around $1000 per year, would be most desirable."

The foregoing installations when totaled do not constitute a large record. The interesting feature, however, is that all of these records indicate positive beneficial results. Also, the installations were made in each case by individuals acting independently, and without previous experience in such work.

Summary of the Art of Economics

Having presented this brief summary of the status of the art, we should like to proceed with a

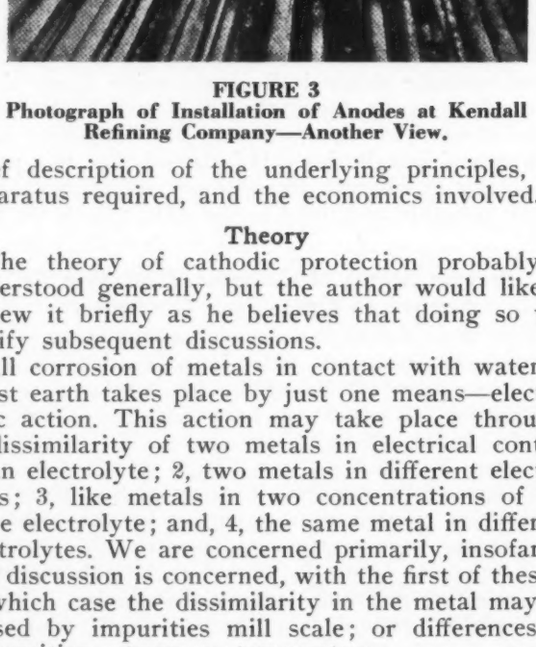


FIGURE 3
Photograph of Installation of Anodes at Kendall Refining Company—Another View.

brief description of the underlying principles, the apparatus required, and the economics involved.

Theory

The theory of cathodic protection probably is understood generally, but the author would like to review it briefly as he believes that doing so will clarify subsequent discussions.

All corrosion of metals in contact with water or moist earth takes place by just one means—electrolytic action. This action may take place through: 1, dissimilarity of two metals in electrical contact in an electrolyte; 2, two metals in different electrolytes; 3, like metals in two concentrations of the same electrolyte; and, 4, the same metal in different electrolytes. We are concerned primarily, insofar as this discussion is concerned, with the first of these—in which case the dissimilarity in the metal may be caused by impurities mill scale; or differences in composition, stress, or temperature.

This action results from the fact that any metal when submerged in an electrolyte assumes a negative potential with respect to the electrolyte. This potential is called "solution" potential, and each kind of metal has a definite and constant solution potential. If two metals with different solution potentials are placed in contact with an electrolyte and also are connected through a metallic circuit, we have an electric battery cell, and current will flow impelled by a voltage equal to the difference between the solution potentials of the two metals. This current flow moves through the electrolyte

from the metal with the greater solution pressure, which is the anode, to the metal with the lesser solution pressure, which is the cathode. This current flow is the movement of acid ions through the electrolyte to the anode—which ions consume the anode at a definite rate—and movement of hydrogen ions to the cathode—where the hydrogen precipitates out of the electrolyte.

The result of this hydrogen in quiet water is to provide an insulating film around the cathode, tending to prevent the further flow of current and the further corrosion of the anode. This condition is called polarization. Any factor which tends to depolarize the cathode, however, thereby will restore the current and corrosion of the anode. Such factors may be the presence of dissolved oxygen which combines chemically with the hydrogen and removes it, or turbulence which washes the hydrogen away, or increased temperature which generally accelerates chemical activity, or increased concentration of acids, alkalies, or other impurities in the electrolyte which increases conductivity of the electrolyte and, hence, the current flow.

Regardless of which of the above factors is predominant, corrosion actually takes place when current flows from the metal into the electrolyte and the metal is anodic. When this current flows back into the metal, the reverse action takes place, and metallic or hydrogen ions in solution tend to precipitate out upon the metal, which at this point is cathodic.

The purpose of cathodic protection is to provide an artificial current which overcomes the small circulating current, reducing or extinguishing the anodic areas and rendering most or all of the metallic areas cathodic (see Figure 4). This can be done by providing artificial anodes consisting of a metal whose solution potential is greater than that of the metal to be protected, such as zinc against iron. The other method is to introduce an external source of direct current between anodes of any metals and the structure to be protected by rendering the structure (in this instance the condenser coils) cathodic. The latter method is the one most generally employed now because of the larger current made available thereby.

Apparatus Required

The installation consists of two items: the anodes and the source of direct current.

The anodes generally consist of a set of steel plates submerged vertically in the condenser tanks from the surface down to close to the bottom, and they are spaced to give a reasonably good current distribution throughout the box. In locations wherein it is difficult to renew steel plates, it might be more economical to use carbon plates or carbon rods. A means of sealing the connections to these carbon anodes for cathodic work has been developed, which method prevents the lead wires from decomposing. The coils are hung from cables or rods fastened in turn to a horizontal structural beam or pipe which, in turn, is suspended from an insulating support. Positive and negative electrical buses are run around the outside of the tank, the positive bus being connected at various points to the horizontal beam or pipe supporting the anodes, and the negative bus being soldered at various points to the tank with taps to the inlet and outlet headers of the coils in the tanks. All electrical connections are soldered solidly or welded.

The source of direct current may be either a motor generator or a rectifier of the copper-oxide, selenium, or tube type. The rectifier has the advantage over a motor generator set in that it is nonsparking in operation and, therefore, is more suitable for operation within the refinery process area. Rectifiers of both the copper-oxide and selenium

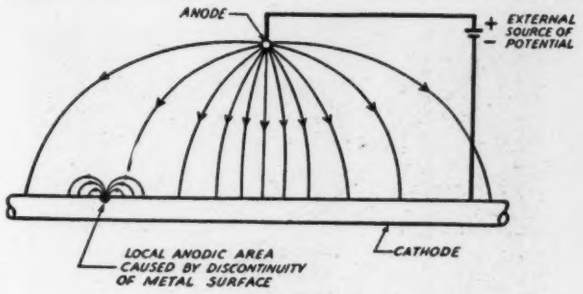


FIGURE 4
Action of Galvanic Currents and Distribution of Protective Currents.

cell type have been developed for outdoor use in connection with pipe lines; have been developed with weatherproof housing; and are generally of rugged construction for operation without attention for long periods in remote locations. The copper-oxide type has been used more generally. All types are provided [by manufacturers] complete with main breakers, voltmeters, ammeters, and tap changing devices for adjustment of voltage and current. They are provided also with a fan to provide increased capacity and a wind relay located in front of the fan, which shuts the unit down should the fan fail.

Points of Design

Successful operation of cathodic-protection units appears to be largely dependent upon the proper spacing of anodes so as to provide uniform current over the entire area of the condenser, which, in turn, will prevent areas remote from the anodes from being under-protected and areas close to the anodes from receiving wasteful amounts of current.

The current requirements are approximately 5 to 10 amperes per 1000 square feet, this value depending in large part upon the degree of uniformity of current distribution. The current requirements are, in the last analysis, whatever is necessary to produce a certain minimum potential of cathodes relative to electrolyte at all points, and we shall go into this point a little further in a subsequent paragraph.

The anodes, in addition to being located properly, should be provided in sufficient quantity to maintain a low circuit resistance in order to save power. Furthermore, the anodes will be consumed at the rate of approximately 20 pounds per ampere per year; and enough metal, therefore, should be provided so that the anodes will last a reasonable length of time.

The rectifier should be mounted as close as practical to the condenser in order to minimize line losses. A typical condenser requires about 6½ volts for a current of 100 amperes. It was found that, unless the rectifier were placed within 100 feet or less of the condenser, or the copper wires made very heavy, the losses in the lines between the rectifier and the condenser would equal the losses in the condenser itself.

As indicated previously, the true criterion of protection appears to be the existence of a definite mini-

mum potential of cathodes with respect to electrolyte at all points. The value of this cathodic potential depends on the method used for measurement. There is considerable room for development in the methods of making these measurements. However, we should like to present a method of measurement which has been used by Sinclair Refining Company,

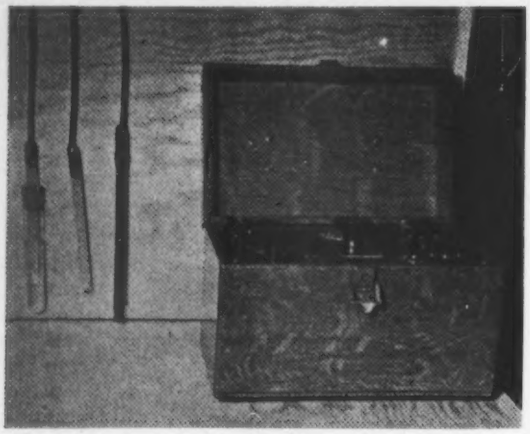


FIGURE 5
Portable Potentiometer, Calomel Cell and Test Electrode for Measuring Cathodic Potentials.

which method was passed along to us through the kindness of Mr. Poole of that company.

The principle of this method of measurement is to compare the potential between a test electrode, consisting of a short length of ½-inch pipe submerged a foot or so below the surface of the water, with the cathode—which, of course, consists of the coils and tank. Instead of measuring this potential directly, however, a calomel cell is used, which in itself is non-polarizing (see Figure 5). Readings are taken between the calomel cell and the test electrode, and also between the calomel cell and the cathode. The difference between the two readings, therefore, represents the difference between the potential of the test electrode and the potential of the cathode. To reduce the effects of polarization further a null-type potentiometer is used.

The potentiometer should read up to approximately 1.10 volts. The calomel cell developed by Sinclair Refining Company is made as follows: A glass tube having an inside diameter of ¼ to ½ inch and a length of 6 to 8 inches, open at one end and closed at the other, is provided with a platinum wire sealed into the closed end. A rubber-covered lead wire is soldered onto this platinum wire, and the connection covered with waterproof insulation. A few drops of mercury then are introduced to cover the end of the platinum wire. An electrolyte is prepared by dissolving 40 grains of potassium chloride in 100 ml of hot water and then adding, with continued stirring, a few grains of mercurous chloride and, lastly, 3 grams of a good grade of chemical agar. This mixture then is poured into the tube and allowed to jell. A plug of paraffin then is placed in the open end of the tube to keep the jelly from drying out, this plug being removed or perforated when the calomel cell is to be used. In making the tests with the above equipment, both calomel cell and test electrode are submerged a few inches below the surface of the water, and both are located remote from each other, and remote from both anodes and cathodes.

In accordance with the foregoing method, proper protection is secured when the potential of the cathode is a minimum of 250 millivolts negative with respect to the test electrode.

Another method of measuring electrolytic potentials which appears to have some advantages is to make use of the exploring electrode for use in surveys for cathodic protection of pipe lines (see Figures 6 and 7). This consists of a button of definite area, made of the same steel as the cathode. This button is provided with an insulating tip ¼ inch long and with a ⅜-inch drill-rod handle about 4 feet long insulated with bakelite tubing. This is operated by pressing the insulated tip against the cathode at various points, and measuring the potential between the button and the cathode by means of a null-type potentiometer.

The advantage of this method is that it can be used to explore various portions of the condenser and to locate points where protection is at a minimum.

A few simple experiments in our laboratories, using both the calomel cell and the exploring electrode, indicated a large disparity between the currents picked up by cathode at points close to, and remote from, the anodes—which was brought out by the exploring electrode, but not by the calomel cell and test electrode.

We should like to see more work done along this

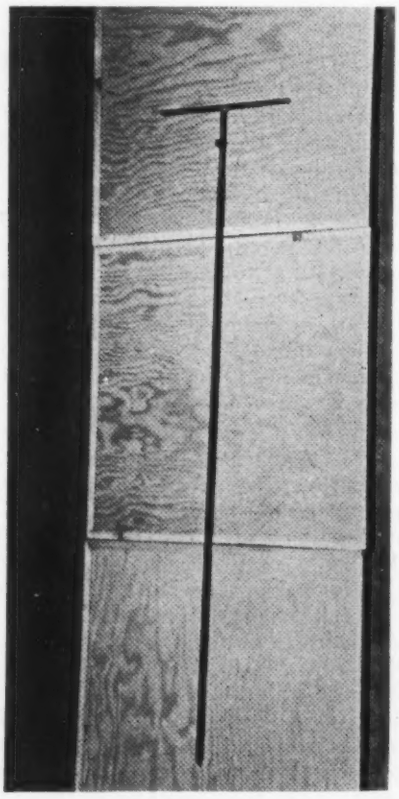


FIGURE 6
Exploring Electrode for Measuring Cathodic Potentials.

line to correlate readings obtained by the calomel cell and test electrode with those obtained by the exploring electrode. Ford, Bacon, and Davis have stated that a negative potential of 250 millivolts of cathode with respect to exploring electrodes in pipeline service is a figure which represents good protection, and we should like also to determine if this

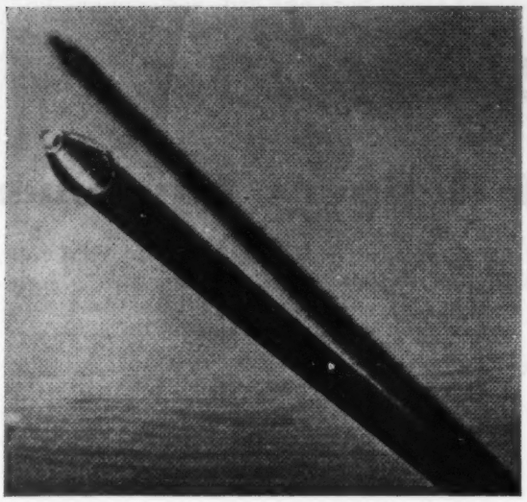


FIGURE 7
Exploring Electrode—Closeup View of Tip.

figure is equally applicable to submerged coils in open-tank condensers.

Economics of Cathodic Protection of Open-Tank Condensers

The cost of the anodes and wiring for the installation at Kendall Refining Company was estimated by the refiner to be approximately $650. The cost of a copper-oxide weatherproof rectifier rated at 10.5 volts, 78 amperes, which is the unit we would recommend for this installation, would be approximately $350. The total cost of the unit, therefore, is approximately $1000 which, when amortized in five years, gives an annual cost of $200. Added to this is the cost of energy which, at 1 cent per kilowatt-hour, will not exceed $60 per year. The total annual cost, therefore, is $260.

The annual cost of replacing coils at Kendall Refining Company, as stated previously, has been approximately $1000 per year. Therefore, if the cathodic-protection equipment is even moderately effective, it will pay out within a short time.

Conclusion

In conclusion, we should like to stress that a great deal has yet to be learned on the subject at hand. As stated previously, the operating records—at least those available to us to date—are meager; on the other hand, what information we do have indicates positive beneficial results.

We hope this discussion will serve to stimulate further investigation by others. The subject particularly needs data from installations in refineries under typical operating conditions.

The records we have all concern locations wherein corrosion was initially very bad. Additional data, however, are necessary to establish the economics involved for the border-line cases.

The Economics of Flue-Gas Recirculation

[*Continued from page 69*]

record of maintenance and repair charges is no longer available for the units which have been described.

Many operating difficulties were encountered. One of the most serious was the depositing of a very adherent hard deposit of ash and tarry materials in the preheater tubes. This presented a difficult and time-consuming cleaning problem, often resulting in mechanical damage to the equipment by the cleaning tools. In addition to this fouling problem, serious corrosion was encountered, especially if too low an exit temperature for the flue gas from the preheater was used, probably resulting in partial condensation of sulfur acids.

The foregoing difficulties, to a large extent, were probably due to the nature of the fuel which was burned in these units. It was the practice at that time, as it is today, to operate the refinery heaters—particularly on the pipe stills—on relatively poor-quality fuel, often containing considerable ash-forming sediment and usually fairly high in sulfur content. Gaseous fuels, in particular, which are used within the refineries are usually very high in sulfur content. This makes the problem of preheater maintenance much more serious than in commercial boilers, for example, for which specification fuels usually are prescribed. It is current practice in normal refinery operation to utilize the poorer-grade fuels, both gas and fuel oil, for firing refinery heaters, because there is usually no other equally economical outlet for these products.

As a result of the maintenance troubles, no new preheaters were installed, and the extisting equipment was kept in operation only until major repairs were required. Their use then was discontinued permanently. The average service life of most of these units was probably not much more than one year.

Summary

Flue-gas recirculation appears to be economically attractive only in the case of existing heaters, which are subject to radiant-section overheating. In the case of new designs there is insufficient advantage to justify the installation of such a system, unless unusually high temperatures are anticipated, and even then there may be preferable alternatives.

Air preheaters, which have been shown to be effective in improving furnace efficiencies, are of doubtful practical utility in ordinary refinery heaters. Experience has indicated that the maintenance and repair costs outweigh the heat savings. At the present low fuel-oil prices, particularly in refineries in the southern part of the United States, the use of air preheaters is even less attractive than formerly.

Any particular installation, of course, must be examined in detail upon its own merit. The above generalizations were drawn from the operation of units which are believed to be fairly typical of those in general use in petroleum refineries. It is, however, entirely possible that differences in fuel quality and cost, along with differences in design and construction costs, may invalidate these conclusions for a particular set of conditions.

BIBLIOGRAPHY

[1] J. E. Bell, U. S. Patent No. 1,574,546 (1926), 1,574,547 (1916), 1,623,773 (1927).
[2] W. L. Nelson, Petroleum Refining Engineer. McGraw-Hill Book Co., New York 1936).

Corrosion Prevention

On the Water Side of Refinery Equipment

A. Chemical Treatment of the Water

W. H. ATTWILL, The Texas Company

INCREASED use of cooling towers has increased considerably water corrosion problems in refinery equipment. Chemical treatment of the water as a corrective measure has been resorted to, and this paper discusses four treatments tried at the Port Arthur, Texas, refinery of The Texas Company.

Sodium-hydroxide and sodium-silicate treatments resulted in little, if any, reduction in the rate of corrosion. Chromate treatment, after 2½ years' use, has proved very effective; and, although it has not entirely eliminated corrosion, the large reduction in condenser-tube losses has more than offset the relatively low cost of treatment.

Sodium hexametaphosphate as a corrosion inhibitor is under trial, and offers a less expensive treatment; but its efficiency is yet to be proved.

This paper was presented to Group Session on Refining, before Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 21, 1941.

IN RECENT years the trend toward the installation of cooling towers to provide large quantities of cool water for condensing and cooling equipment often has resulted in serious corrosion on the water side of refinery equipment. Some of the waters used for makeup to these cooling towers are not corrosive and, when concentrated, tend to form a protective coating—usually of calcium-carbonate nature—on the surface of the metal with which they come in contact. Other makeup waters, however, which may or may not be normally corrosive, when concentrated several times and completely saturated with dissolved oxygen in cooling towers, become very corrosive to the metals generally used in refinery cooling sytems.

Several steps have been taken by members of the oil refining industry to reduce the water corrosion in these cooling-tower systems, the most commonly used method being the chemical treatment of the circulating water. Although the object of this paper is to discuss the practical application and results of the chemical treatments applied to several of the recirculated cooling-tower systems at the Port Arthur, Texas, refinery of The Texas Company, a few words should be said first about the theory behind these treatments.

Theory of Chemical Treatments

Practically all forms of chemical treatments applied to cooling waters for corrosion control have, as their object, the formation of a more or less impervious film on the surface of the metals in contact with the water. Many chemicals have been used for this purpose—among them sodium hydroxide, calcium hydroxide, sodium carbonate, sodium silicates, sodium phosphates, sodium dichromate, sodium hexametaphosphate, and certain organic compounds. The films produced by these corrosion inhibitors may be of appreciable thickness, such as are formed by the silicates, or they may be so thin as to be practically invisible. In the case of the chromates, the corrosion-resistant coating produced is said to be an invisible film of ferric and chromic oxides.[1]

The efficiency of a chemical treatment depends upon how complete and impenetrable the film becomes. If the film formation is not complete, rapid localized corrosion may result from the setting up of concentration cells. In chemically treating cooling water for corrosion control, it is always wiser to overshoot the mark than to court the danger of having insufficient inhibitor present.

In less than one year after the installation, in 1935, of two large cooling towers at the location mentioned, water corrosion problems increased and became progressively more severe as additional towers were installed. During the following years the use of special condenser-tube alloys in certain locations, and the use of better makeup water to some of the cooling towers, decreased—but by no means eliminated—the corrosion problem, and it became evident that some corrective steps must be taken if any material reduction in water corrosion was to be accomplished. The application of chemical treatments seemed to offer the most likely solution.

Caustic and Silicate Treatments

Four chemical treatments have been tried to date in one or more cooling-tower systems. The first treatment applied was the daily addition of sodium hydroxide to a natural-draft type of cooling-tower system, with a circulating rate of 7000 gallons per minute, to maintain a pH (hydrogen-ion concentration) of 8.0 to 8.5, as compared to a former pH of 7.0 to 7.5. After a three months' trial this treatment was discontinued, as no reduction in corrosion was obtained. Sodium-silicate treatment was attempted next, in five cooling-tower systems, being added in sufficient amounts to increase the alkalinity approximately 25 ppm; but, after trials for periods as long as 7 months, no improvement was noted. If anything, the silicate treatment aggravated condi-

tions by binding the dirt and iron oxide present in the cooling water, with the resultant stoppage of water-supply lines and condenser tubes. There are many types and strengths of sodium silicates, however, and it is entirely possible that better results would have been obtained with other forms of silicates than the one used.

Chromate Treatment

Following these failures, the addition of sodium dichromate was tried in a mechanical-draft type of cooling-tower system with a capacity of 1000 gallons per minute, where serious water corrosion had been taking place. A great reduction in corrosion of both the copper-base condenser tubes and the steel and cast-iron water-supply lines was immediately apparent.

An example of this reduction in corrosion is illustrated in Figure 1. The upper half of Figure 1 shows the corrosion, after 270 days' service, on a piece of 3-inch standard steel pipe taken from the outlet-water line of one of the condensers before chromate treatment was started. The sereve pitting best can be seen by observing the wall thickness at the right. The lower half of Figure 1 shows the corrosion on a piece of 3-inch standard steel pipe, from the same location, after 241 days' service with the chromate-treated water. The great reduction in corrosion can be observed readily. It is interesting to note that the small amountof corrosion that did take place in the latter specimen is of a uniform nature, with no deep pits in evidence.

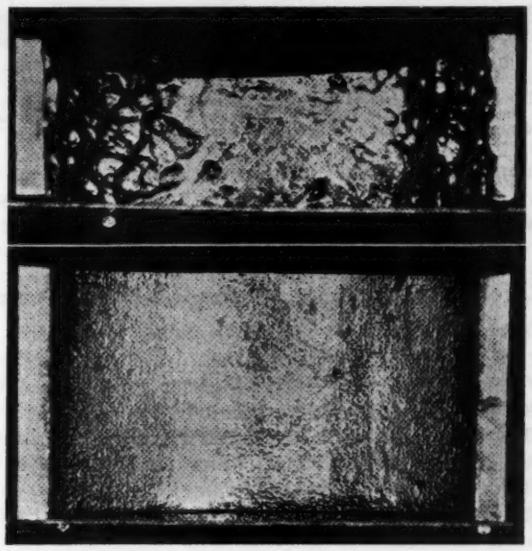
After the success obtained with the chromate treatment in this first location, the treatment gradually was extended to other cooling-tower systems. At the present time, this method of corrosion control is in use in 5 cooling-tower systems, 3 of the mechanical-draft and 2 of the natural-draft tvpe, with a total circulating capacity of 36,000 gallons per minute.

Chromate Treatment in Mechanical-Draft Towers

In applying the chromate treatment to mechanical-draft cooling towers, a concentration of 500 ppm. of chromate—as $Na_2Cr_2O_7 \cdot 2H_2O$—is maintained in the circulating water by the daily addition of sodium dichromate. Sufficient caustic is added to convert the dichromate to the normal chromate and give a pH of 8.0 in the water. Small amounts of sodium hexametaphosphate also are added daily, so as to give a concentration of 5 to 10 ppm of total phosphate, as PO_4. Experience indicates that the presence of a few parts per million of the metaphosphate (and the orthophosphate resulting from its conversion) tends to keep the condenser tubes and supply lines free from mineral and corrosion deposits. The presence of phosphate is said also to improve the corrosion-resistant properties of the chromate film.[2]

As the windage loss from mechanical-draft towers is negligible, it is necessary to control the total solids concentration of the circulating water by bleeding off some of the concentrated water. This is done by continuous blowdown from the tower system, regulated to limit the sodium-chloride concentration to about 850 ppm. With a makeup water of approximately 120 ppm of sodium chloride, this allows 7 concentrations in the circulating water. A typical analysis of the cooling-tower makeup water is given in Table 1.

Best results from this treatment naturally are obtained with an entirely new cooling-water system; but results in an already corroded system are often more evident, because it permits a comparison with the conditions before treatment. In one of the newer cooling-tower systems that has received



Top: 270 days, without chromate.
Bottom: 241 days, with chromate.

FIGURE 1
Reduction in Water Corrosion with Chromate Treatment.

chromate treatment since its installation, more than 11,000 red-brass condenser tubes have been in water service for more than 18 months without any replacements; and, in a second system of more than 3000 red-brass tubes, no failures have occurred in 26 months. Examination of the equipment shows very little corrosion in the steel and cast-iron water-supply lines and cast-iron condenser heads. Failures of red-brass tubes usually begin to occur within a few months, and the tube bundles require replacement within 18 to 24 months in similar service without chromate treatment.

Test pieces of various metals placed in the outlet-water boxes of condensers before and after chromate treatment show a 75-percent or better reduction in corrosion on boiler steel, and practically no corrosion on red brass and admiralty metal.

Chemical costs of the chromate treatment in mechanical-draft cooling towers have averaged about $35 per month per 1000 gallons per minute of water circulated; but this cost is justified amply by reduc-

TABLE 1
Typical Analysis of Makeup Water

	Parts Per Million
Residue on evaporaton	236.0
Organic and volatile	51.0
Suspended matter	29.0
Iron oxide and alumina (R_2O_3)	18.2
Silica (SiO_2)	32.5
Calcium (Ca)	11.5
Magnesium (Mg)	5.4
Sodium (Na)	50.4
Sulfate (SO_4)	18.5
Chloride (Cl)	73.2
Carbonate (CO_3)	0.0
Bicarbonate	46.3
Free Carbon dioxide (CO_2)	1.0
pH*	7.2

* Hydrogen-ion concentration.

TABLE 2
Tubes in Service and Tube Replacements on Condensers in Use in Cooling-Tower Systems

Year	Tubes in Service	Tubes Replaced	Replace- (Percent)
1936	44,415	11,867	27
1937	51,002	8,566	17
1938	55,867	20,437	37
1939	57,306	6,955	12
1940	73,025	5,721	8

Chromate and threshold treatments first started in 1939, and extended to other towers during 1939 and 1940. Tubes in service only a part of one year are averaged to show the number in service a full year.

tion in corrosion in condenser tubes and water-supply lines, better heat-transfer rates, fewer shutdowns, and generally better operation of the refining units.

Chromate Treatment in Natural-Draft Towers

During the past year chromate treatment was started in two natural-draft cooling-tower systems. Because of the relatively high windage loss from these towers, chromate concentration has been held at 100 to 150 ppm in order to reduce the chemical costs. Caustic and sodium hexametaphosphate have been carried at the same concentrations as in the mechanical-draft towers. Although it is too early to predict the amount of corrosion reduction that will be obtained with this lower chromate concentration, indications are that an appreciable decrease will be secured. The cost of the chromate treatment in natural-draft towers has averaged approximately $20 per month per 1000 gallons per minute of water circulated.

Hazards of Chromate Treatment

A word or two of warning should be given about the chromate treatment. Operators handling the sodium dichromate should wear rubber gloves and should be careful to avoid any contact of the chemical with the skin, or the so-called "chrome itch" might result. The hands and wrists should be washed carefully with fresh water after the chemicals have been handled. The chromate-treated water itself is not believed to be dangerous, due to the relatively low concentrations of chromate present; but it is advisable to prevent, as much as possible, its contact with the skin. In 2½ years' experience with this treatment, no trouble has occurred from the sources mentioned.

Because of windage losses, chromate-treated water in a natural-draft tower will deposit a thin greenish-yellow film on the surrounding equipment; but this film has been no more noticeable than the iron-oxide coating deposited by untreated water. Under certain conditions, however, this feature might be objectionable.

Sodium-Hexametaphosphate Treatment

Sodium hexametaphosphate has been used for several years to retard calcium-carbonate deposition from scale-forming waters. The apparent reason for this phenomenon is the adsorption of hexametaphosphate on the surface of the metal.[3] With this film formation on the metal in mind, it was decided to try the so-called "threshold treatment" in two cooling towers to determine if the film produced would retard corrosion. If successful, the treatment would give low-cost corrosion control that would be particularly adaptable to natural-draft towers with their high windage losses.

The threshold treatment was started on the first tower in August, 1939, and extended to the second tower in January, 1940. In this treatment a concentration of 2 to 5 ppm of sodium hexametaphosphate is maintained in the circulating water by the addition of the required amount of metaphosphate once every 6 hours. Suffcient caustic also is added to maintain a pH value between 7.5 and 8.0. Although the corrosion-reduction properties of this treatment have not been well established, there are indications that some reduction in corrosion may be obtained, but to a definitely lesser extent than with the chromate treatment. The threshold treatment recently has been recommended for the control of cold-water corrosion.[4] Cost of the threshold treatment has averaged $10 a month per 1000 gallons per minute of water circulated.

Reduction in Condenser-Tube Corrosion

Table 2 shows a tabulation of condenser-tube losses in cooling-tower systems before and after chemical treatment had been established. The table shows the high rate of replacement before the chromate and threshold treatments were started in 1939, and the reduction in these losses as the treatments were extended to additional tower systems. As some of these treatments were not started until well along in 1940, a still greater reduction is expected in 1941.

BIBLIOGRAPHY

[1] T. P. Hoar and U. R. Evans, "The Passivity of Metals, Part VII: The Specific Function of Chromates," *J. Chem. Soc.* (London), Part II, 2476-81 (1932).

[2] F. N. Speller, *Proc. Am. Soc. Testing Materials* **36,** Part II, 695-6 (1936).

[3] G. B. Hatch and Owen Rice, "Surface-Active Properties of Sodium Hexametaphosphate," *Ind. Eng. Chem.* **31,** 51-7 (1939).

[4] G. B. Hatch and Owen Rice, "Corrosion Control with Threshold Treatment," *Ind. Eng. Chem.* **32,** 1572-9 (1940).

B. Use of Deaerator

W. H. ATTWILL, The Texas Company

MOST of the corrosion-control work on refinery cooling-water systems may be classified under three general methods: 1, the use of corrosion-resistant metals and alloys; 2, the use of chemicals to deposit a protective film on the metal; or, 3, the application of cathodic protection. All of these methods have been successful in some cases, and have failed in others. A new development in this field is the mechanical deaeration of refinery cooling water.

Experience shows that, in a corrosive water that is normally alkaline, dissolved oxygen is the main factor in corrosion. Eliminate the dissolved oxygen and you eliminate the corrosion, whether it be the dezincification-type corrosion of admiralty con-

THE mechanical deaerator described in this paper greatly retards water corrosion in condenser tubes and water-supply lines by removing 98 percent of the dissolved oxygen from the cooling water. The deaerating equipment is reliable in operation, requiring little attention and maintenance, and may be used with equal efficiency on either a "recirculated" or "once-through" cooling-water system. Installation cost is high, but operating costs are relatively low.

denser tubes, the pit-type corrosion of red-brass tubes and steel pipe, or the general corrosion of cast iron.

Deaeration long has been used for the removal of dissolved oxygen from boiler feed water, but only recently has this principle been applied to corrosion control in refinery cooling-water systems. The methods of deaeration differ, however, in that in most cases heat—in the form of steam—is used in the deaeration of boiler feed water, whereas a high vacuum is employed in cold-water deaeration.

Two years ago The Texas Company, in an attempt to reduce cooling-water corrosion, installed a

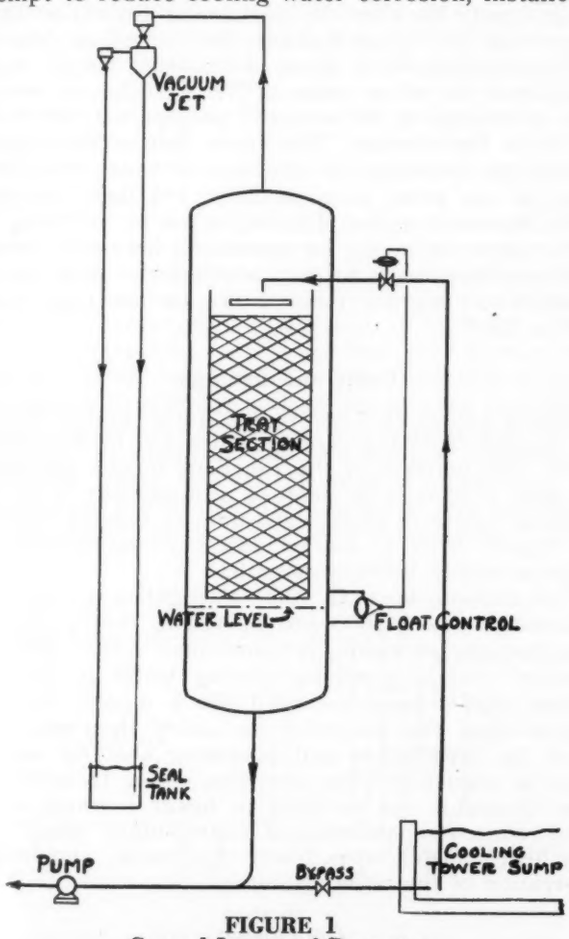


FIGURE 1
General Layout of Deaerator.

mechanical deaerator on one of the recirculated cooling-tower systems at its Port Arthur, Texas, refinery. This deaerator is installed on a recirculated system utilizing a forced-draft type of cooling tower, with a circulating rate of 1500 gallons per minute. All the waters available in this area are normally corrosive non-scale-forming waters. The makeup water to this particular system is of low chloride low hardness content, and gives a pH of 8.0 to 8.5 when concentrated in the cooling tower.

Details of Deaerator

The general arrangement of the deaerator is shown in Figure 1. The cold water from the cooling-tower sump is drawn into the 6x20-foot deaerator tower by the high vacuum maintained by a 2-stage vacuum jet. A diaphragm-operated inlet valve regulates the flow of water to hold a level just below the tray section. As the water passes down through the tray section, it continually is broken up into films or sheets, exposing as much water surface as possible to the high vacuum. Under these conditions, most of the oxygen is released from the water and is drawn out through the vacuum jet. A single-stage centrifugal pump takes suction on the bottom of the deaerator tower and discharges to the refining unit.

The construction of the deaerator is in many ways similar to that of the one installed in Louisiana by a large sulphur company to protect a steel line in cold-water service.[1] The two-stage vacuum jet was selected in preference to the vacuum pump because of its simplicity and reliability. The jet was designed to maintain a vacuum of 29.0 inches mercury (referred to a 30-inch barometer) in the tower, and in actual operation the vacuum varies between 28.8 inches and 29.6 inches (referred to a 30-inch barometer), depending upon the circulating-water temperature. The tower itself was made from a second-hand vessel, and was coated carefully on the inside with a heavy layer of hot asphalt to retard the severe corrosion which otherwise would be expected to occur under the conditions of operation.

The tray section, on which the ultimate efficiency of the deaeration process depends, is of cypress-wood construction. It is designed to give an appreciable time element before the entering water reaches the bottom of the deaerator, and to provide ample venting of the tray areas for the easy removal of the gases released.

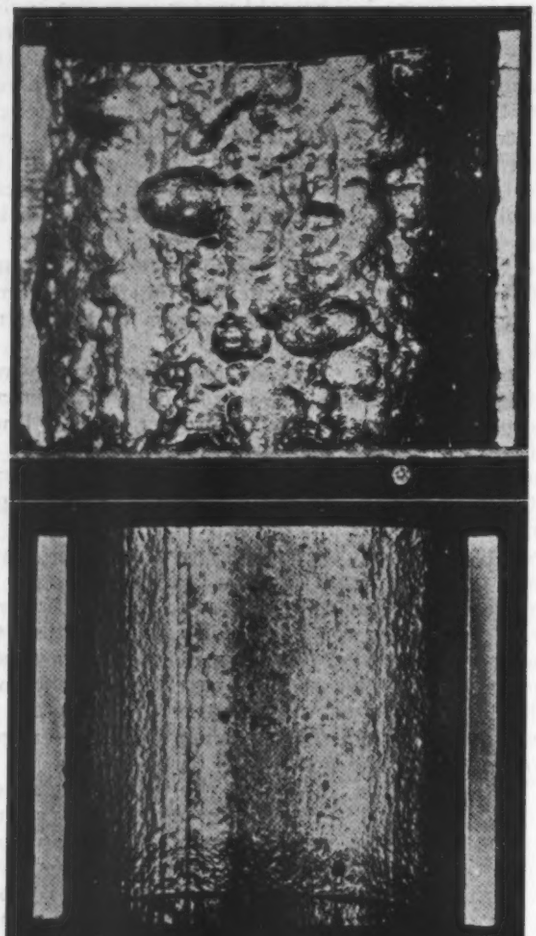
Of primary importance, if the high vacuum mentioned above is to be attained, is a complete absence of leaks in the entire equipment. Leaks above the water level reduce the vacuum by loading up the jets, whereas leaks below the water level actually contaminate the deaerated water with oxygen. Some trouble was experienced from this source during the initial stages of operation, but the liberal application of hot asphalt on all joints and connections eliminated this difficulty.

Oxygen-Removal Efficiency

Samples of water taken from the base of the deaerator during the past year show an average oxygen content of only 0.12 ppm of oxygen, by the Winkler test, as compared with 6 to 7 ppm in the water entering the deaerator, or an oxygen removal of about 98 percent. The actual water supplied to the refining unit has had a slightly higher oxygen content, averaging about 0.2 ppm, because of packing gland leakage in the centrifugal pump, which operates under a suction condition of 20 inches of mercury vacuum.

Previous to the installation of the mechanical deaerator, serious water corrosion took place on the refining unit supplied by this cooling-tower system.

Six of the nine water-cooled admiralty condenser-tube bundles failed completely after only nine months' service, and two of the three remaining bundles failed four months later. Six of these failures were replaced with red-brass, one with copper-nickel, and the other with arsenical admiralty-metal tubes. Red brass was used instead of admiralty, as more recent experience indicates that red-brass tubes have, on the average, slightly longer life than admiralty-metal tubes for our particular conditions.



Top: 268 days, without deaeration.
Bottom: 181 days, with deaeration.

FIGURE 2
Reduction in Water Corrosion with Mechanical Deaeration.

TABLE 1
Typical Analysis of Makeup Water

	Parts Per Million
Residue on evaporation	181.0
Organic and volatile	20.0
Suspended matter	5.0
Iron oxide and alumina (R_2O_3)	2.0
Silica (SiO_2)	5.1
Calcium (Ca)	1.0
Magnesium (Mg)	0.2
Sodium (Na)	67.2
Sulfate (SO_4)	31.8
Chloride (Cl)	60.6
Carbonate (CO_3)	0.0
Bicarbonate (HCO_3)	37.5
Free carbon dioxide (CO_2)	1.0
pH	7.5

Analysis of cooling-tower makeup water, both before and after the installation of the deaerator, has remained essentially the same.

Since the installation of the deaerator two years ago, no failures have occurred from water corrosion in any of these condensers.

Just before the construction of the mechanical deaerator a new test bundle, using steel tubes, was installed. This steel bundle now has been in service for 26 months without a tube failure—which is considered a remarkable record, inasmuch as our average life of steel tubes in water service is only 5 months.

Corrosion Reduction in Water Lines

Prior to the installation of the deaerator, severe water corrosion also took place in the steel and cast-iron water-supply lines. Tuberculation became so extensive in these lines that the centrifugal-pump discharge pressure increased from 47 psi to 63 psi, with a corresponding drop in the quantity of cooling water supplied to the unit. The pressure drop through the piping was reduced before the deaerator installation by circulating hot inhibited acid through the entire cooling system of the unit. Since the deaerator has been in operation, no increase in pressure drop has been noted.

Figure 2 shows the reduction in corrosion on these supply lines by the mechanical deaerator. The upper half of Figure 2 shows the corrosion, over a 268-day period, on a piece of standard 2-inch steel pipe, from the water outlet of No. 6 condenser, without deaeration of the water. This pipe actually had failed in the threads. The lower half of the figure shows the corrosion on a section of 2-inch standard pipe in the same location, after 181 days' service with deaerated water. The reduction in corrosion is self-evident. It might be mentioned here that these test specimens were located where the cooling water reaches the highest temperature on the unit, viz., 160 to 170° F.

Costs and Savings

The use of sodium sulfite to remove the last traces of oxygen from the cooling water has been considered; but in view of the excellent results obtained to date, it cannot be justified economically. Cost of sodium sulfite to remove 0.2 ppm of oxygen, plus 1 to 2 ppm of excess sodium sulfite, would amount to approximately $100 per month.

Installation cost of the 1500-gallon-per-minute deaerator was $8100; and operating costs—including vacuum-jet steam, jet condenser water, and increased cost of pumping cooling water to the refining unit— have averaged $50 a month. In two years' time the deaerator has more than paid for both its installation and operating cost by reduction in condenser-tube corrosion alone. In addition, the deaerator has resulted in lower pressure drop and reduced repair costs of water-supply lines, better heat-transfer rates, fewer shutdowns, and better operation of the refining unit.

Conclusion

In conclusion, mechanical deaeration of refinery cooling water for corrosion control has the following advantages and disadvantages:

1. Water corrosion is reduced considerably in the entire cooling system, not just in individual pieces of equipment.
2. The deaerating equipment is reliable in opera-

tion, requiring little attention and maintenance.
3. The installation cost is high, but operating costs are relatively low.
4. Mechanical deaeration may be applied to both "recirculated" and "once-through" cooling-water systems with equal efficiency, and with the same installation and operating costs.

BIBLIOGRAPHY

[1] S. T. Powell and H. S. Burns, "Vacuum Deaeration Combats Cold-Water Corrosion," *Chem. Met. Eng.* **43,** 180-84 (1936).

C. Cathodic Protection

V. L. NEALY, The Texas Company

AS A RESULT of the success obtained in cathodic protection of pipe lines, considerable attention again has been given recently to the prevention of electrolytic corrosion in condensers and similar equipment by the same method.

Prolonged life of condenser-tube bundles, operating under severe conditions and protected with counter-electrical currents, has proved the merits of cathodic protection in several instances.

Closely allied with cathodic protection is the insulation of pipe connections to condensers to prevent the flow of current *in* or *out* of the bundles. This has been successful in at least one installation.

Cathodic protection of condensers definitely has been proved an economical method of corrosion prevention, but much investigation remains to be done in the development of empirical formulas or equations from which the current density necessary under widely varying conditions of operation can be solved.

CATHODIC protection of a metallic surface is based on the fundamental concept that corrosion in an aqueous solution invariably is accompanied by a current discharge from the metal (electrode) to the water (electrolyte). Hence, if the surface of the electrode can be maintained at a potential sufficiently below that of the electrolyte, no current discharge will occur.

In practice, this is accomplished by raising the potential of the water with the aid of one or more anodes supported in the water passageways, and insulated from the vessel. Because the current is forced to travel from the anode to the water and then to the shell, the water necessarily must be positive to the latter, so that further corrosion is inhibited. Of course, the anodes are more or less rapidly dissolved, but their replacement cost is negligible in comparison with that of a condenser-tube bundle, for example.

Although cathodic protection of boilers and condensers has been attempted for a number of years with some degree of success, it has remained largely in the experimental stage. Recently, since the general acceptance of this method of corrosion prevention as applied to underground pipe lines, a renewed interest has been taken in protection of condensers, with pipe-line experience serving as a basis or background for the design and operation of cathodic-unit installations on condensing equipment. However, there are several notable differences in application and in checking operation. For example, in pipe-line service, the degree of protection ordinarily is determined by potential measurements; whereas, in condensers, the current density per square foot of surface area is the criterion, as it is mechanically difficult to measure the potential existing in constricted passageways.

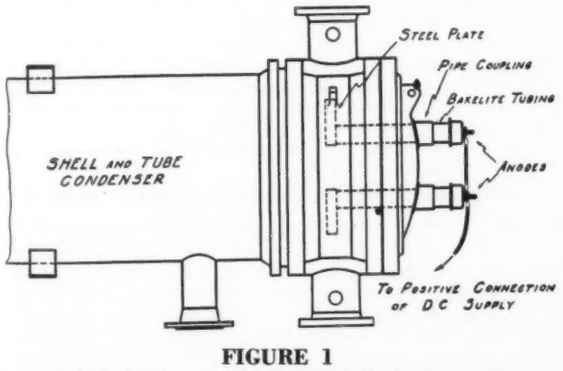


FIGURE 1
Anode Installation in Fixed-Head End of Condenser.

To consider an actual application of condenser protection, refer to Figures 1 and 2, in which are illustrated the details of the anode installations for the fixed-head and floating-head ends, respectively, of a shell-and-tube type of unit. In the former it will be noted that an anode consists simply of a steel plate supported by a steel rod, which is insulated from the head by means of a bakelite tube threaded into a pipe coupling. The floating-head end contains anodes of similar design, with the addition of packing glands on the shell cover to allow for expansion and contraction.

This condenser is a two-pass type, having kerosine outside and water inside the tubes, which are made of red brass. The cooling water is untreated—taken directly from the Neches River below Beaumont, Texas—and contains widely varying concentrations of organic matter and salts, principally sodium chloride.

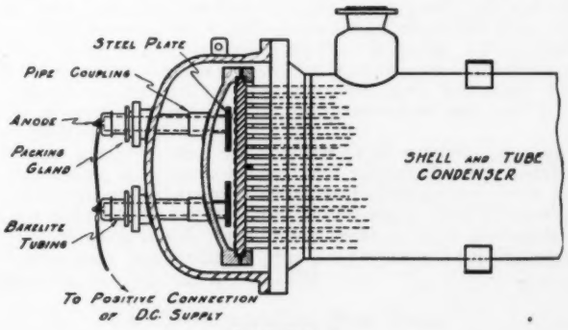


FIGURE 2
Anode Installation in Floating-Head End of Condenser.

Tube failures at this condenser previously had occurred every 3 to 6 months in new bundles, as com-

pared with a present service of 15 months to date without failure.

The direct current is obtained from a motor-generator set supplying approximately 1¾ amperes—at varying voltages to correspond to varying cooling-water salinity or conductivity—to each of the 4

Multi-Unit Installation

Figure 3 is a schematic diagram of cathodic protection of 16 shell-and-tube-type condensers and coolers located on a pipe still, showing the general arrangement, wiring, number of anodes in each unit, and operating data—including the surface area and total current for each condenser. A copper-oxide rectifier supplies current to all of the units; and the distribution is controlled by means of variable re-

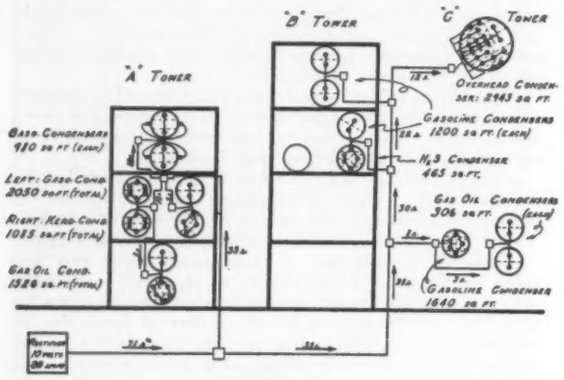


FIGURE 3
Schematic Diagram: Cathodic Installation at a Pipe Still.

sistors in most of the junction boxes, which are indicated by small squares on the diagram.

One feature of this installation which is considered important is the method of returning the current. Instead of a single negative connection to the base of one of the towers, an insulated negative return wire was run with the positive feeder and grounded to each condenser individually. This prevents the random circulation of large currents throughout the framework and other operating equipment of the still.

The cooling water is untreated, and has its source in the ship channel just below Houston, Texas. This water is even more contaminated than the former example cited. Sulfates and chlorides predominate.

Insulating Gaskets

Very closely allied with cathodic protection of condensers is the insulation of piping to and from a unit by means of insulating gaskets and bolt sleeves at a flanged connection. This expedient serves to interrupt the normal current flowing in the piping, and thus prevents electrolysis as a result of current entering a condenser and discharging from either the shell or the tubes. However, insulation should be done advisedly, because very often the electrolytic action is localized and cannot be relieved in this manner. Furthermore, serious damage to other adjacent equipment or piping can be caused by improper insulation.

One successful installation was made at a battery of crude stills where heavy, fluctuating currents were measured on the vapor-inlet lines to several condensers, which currents resulted in severe corrosion of the red-brass tubes. Apparently, the currents had been generated by the turbulence of hot vapors in the piping, and were discharging to the water from the tubes. All connections to the condensers were insulated, including the supporting cradle for each shell. No further trouble from corrosion was experienced.

Conclusion

That cathodic protection of condensers and other equipment in water service can be applied successfully and economically as a corrosion-preventive measure is assured in many instances. The current-density requirements under different operating conditions are not yet known definitely. Such variables as the temperature, salinity of the water, composition of the metals present, design of the anode system, and rate of flow of the cooling water are a few of the more important factors influencing the current needed for protection. However, as more installations are made under different conditions, answers to the aforementioned problems should be forthcoming.

1940 Road Detonation Tests

Compiled from Report of the Cooperative Fuel Research Committee

By J. M. CAMPBELL,* R. J. GREENSHIELDS,† and W. M. HOLADAY‡

THE 1940 CFR road tests have developed new information that can be used for the development of fuels and engines. Application of the principles worked out in these tests is expected to result in a more efficient utilization of fuel anti-knock properties and more effective engine design and adjustment to meet the requisites of current motor fuels.

The tests indicate that the ASTM octane number alone, or even a road octane number as determined by methods heretofore widely used, does not give sufficient information for present needs relative to fuel behavior in service. Neither do test methods previously used provide sufficient information concerning the fuel requirements and knocking characteristics of the engines. The new methods of approach which have been developed furnish needed information relative to the fuel and engine relationship that heretofore has been obscure, and indicate paths for future developments.

The entire program has been supported generously by the cooperating organizations and their respective representatives who actively participated in the tests. Various phases of the work have extended over most of the past year and, in the concluding and most important stage—the centralized road tests at San Bernardino, California — 32 organizations were represented. In these concluding tests, a study was made of the characteristics of 23 fuels representing a wide variety of fuel types and the complimentary behavior of 24 different automobiles. During this latter period alone, the 24 test cars were driven over 100,000 miles.

This report was presented to Division of Refining, before the Eleventh Mid-Year Meeting of the American Petroleum Institute, at the Mayo Hotel, Tulsa, Oklahoma, May 22, 1941.

OVER the past 10 years the Cooperative Fuel Research Committee, which is sponsored by the American Petroleum Institute, the Automobile Manufacturers Association, the Society of Automotive Engineers, and the National Bureau of Standards, has given considerable attention to the problem of evaluating the knocking characteristics of motor fuels, both by laboratory tests and by actual road tests. The results of these investigations have been made public from time to time through the publications of the American Petroleum Institute,[1] and those of the Society of Automotive Engineers.

Basically what has been sought is some procedure or procedures for the evaluation of the knocking characteristics of different motor fuels in service and the corresponding behavior of engines. This program was divided into two parts: Part I, in which a number of cooperating laboratories each rated a selected group of fuels by whichever procedure it then was using; and Part II, consisting of centralized tests made after completion of Part I, and in which an effort was made to find an improved approach to the entire problem.

Part I—Cooperative Exchange Road Tests

The purpose of this part of the program was to obtain some facts about the type of information that was being supplied by the road-test procedures then in use. If the road ratings obtained independently by different laboratories did not agree within reasonable limits, then there could be no question as to the desirability of further intensive work on the problem. On the other hand, if the results obtained in this way showed substantial agreement among different laboratories, then there might be considerable question as to the necessity of conducting extensive centralized tests.

Invitations to participate in this part of the program were issued on February 7, 1940, to members of the Cooperative Fuel Research Committee, the CFR Motor Fuels Division, the CFR Motor Fuels Exchange Group, the Pacific Coast Technical Group, and to all participants in previous CFR road tests. This invitation carried with it a questionnaire requesting each company to list the type of gasolines that it would be in a position to supply for the project, with the understanding that each laboratory might be called upon to furnish one or two gasolines. On the basis of the response to these questionnaires a group of 15 fuels ranging from 70 to 83 ASTM octane number was selected. For the most part, each cooperating company supplied one fuel to all the cooperating laboratories and received in return one drum of all the other experimental fuels from the other suppliers. For this reason these tests have been referred to as the "cooperative exchange road tests."

Results of Part I—Cooperative Exchange Tests

The findings of the group appointed to analyze the data are summarized in Table 1.

Typical of the variations reported in different cars, even among different units of the same make, are those given by one company in Table 2. It is obvious from data of this kind that the road ratings as reported in this part of the program by any one company on a limited number of cars largely are affected by chance. It is not surprising, therefore, that the average road ratings reported by each laboratory and listed in Table 1 show considerable variation among different laboratories. For example, the 15 laboratories employing the original CFR road-test method with minor changes show differences in the road ratings of individual fuels varying from 3.0 to 12.3 octane numbers.

The magnitude of these variations is dependent to some extent on the characteristics of the fuel itself, and to some extent on the chance selection of cars. Laboratory F, which used 18 cars altogether, had the smallest average deviation from the average, and seldom differed from the average by more than 1 octane number. On the other hand, laboratories using only from 1 to 4 cars sometimes deviated from the average in their interpretation of fuel behavior by as much as 4 or 5 octane numbers. All this follows, of course, from the statistical nature of this method, and indicates how easily a misinterpretation of fuel behavior can be made from limited data.

On the basis of this information it is evident that anti-knock quality, as expressed by road ratings by any method then current, varied from laboratory to laboratory by a significant amount. Because of this situation, a plan to conduct a series of centralized road-knock tests at San Bernardino, California, was approved by the Cooperative Fuel Research Committee on September 6, 1940.

Part II—Centralized Road Tests

The purpose of these tests was to study cooperatively the problem of evaluating the knock characteristics of fuels and engines. Invitations to participate in these tests again were sent out to the membership of the Cooperative Fuel Research Committee, the CFR Motor Fuels Division, the CFR Exchange Group, and the Pacific Coast Technical Group. Invitations also were extended to the Ordnance Department and to the Quartermaster Corps of the U. S.

* General Motors Research Laboratories, Detroit.
† Shell Oil Company, Wood River, Illinois.
‡ Socony-Vacuum Oil Company, New York.

TABLE 1

Average of Individual Car Ratings Reported by Various Companies in Exchange Road Tests, Part I

General Description of Road-Test Method	Laboratory	Number of Cars	ROAD RATING—OCTANE NUMBER														Average Deviation from CFR Average
			23P	24P	25P	26P	27P	28P	31R	32R	33R	34R	35R	36R	37R	38R	39R	
CFR	A	6	78.9	82.4	73.9	84.9	87.2	82.8	70.7	75.8	71.8	74.8	70.0	77.3	73.5	74.1	75.6	1.02
CFR	B	4	....	....	71.9	....	....	....	70.4	68.7	68.1	72.1	72.2	75.5	71.7	69.8	74.8	2.21
CFR	C	6	78.3	80.3	73.8	....	....	80.3	70.7	77.3	71.1	73.4	70.2	74.8	....	74.2	74.3	1.00
CFR	D	4	80.3	82.3	75.0	79.3	80.6	79.3	71.1	70.2	69.2	72.0	72.0	77.0	73.1	72.1	74.6	1.59
CFR	E	3	81.2	83.3	76.0	83.3	80.5	80.7	70.7	70.2	71.3	73.7	70.2	77.3	74.0	69.2	76.8	1.54
CFR	F	18	79.8	82.0	75.9	82.4	82.3	80.1	71.5	73.3	71.8	73.9	71.5	76.0	72.9	72.4	75.4	0.65
CFR	G	3	82.0	83.5	73.0	80.5	81.5	76.5	70.5	74.5	70.0	72.8	76.5	74.8	71.8	72.3	73.3	2.04
CFR	H	6	79.9	81.6	75.7	83.6	84.8	81.4	71.0	75.5	72.6	75.1	72.0	77.5	74.6	75.8	76.5	0.85
CFR	I	4	78.3	79.7	72.6	82.6	83.7	79.6	70.0	74.8	72.0	73.6	69.3	76.0	71.9	74.7	74.6	0.98
CFR	J	4	78.6	80.1	73.1	85.0	88.9	81.7	69.7	77.0	72.3	73.8	71.6	76.0	74.2	75.2	76.2	1.27
CFR	K	3	80.7	82.3	77.3	85.0	90.7	83.0	73.3	81.0	73.7	76.7	73.3	80.0	74.7	73.3	80.0	2.72
CFR	L	6	79.5	82.0	73.5	84.0	85.0	82.0	71.0	73.0	71.5	73.0	70.0	77.0	73.0	75.0	77.0	0.89
CFR	M	1	81.0	82.0	76.0	83.5	89.5	81.5	71.5	78.0	74.0	75.0	72.5	77.0	73.5	75.0	75.5	1.33
CFR at trace spark	N	8	77.8	78.8	74.8	84.0	84.1	83.3	69.5	77.5	74.8	75.2	69.5	76.5	74.0	76.4	76.6	1.62
CFR at trace spark	O	2	78.5	78.6	74.2	81.3	80.8	75.3	73.0	74.5	72.0	73.7	72.0	73.8	73.7	72.1	73.9	1.59
Aggregate	P	2	80.0	80.9	68.7	77.7	81.4	77.7	72.3	....	66.9	68.7	73.1	75.2	70.3	69.9	72.1	2.76
Aggregate, 10-45 mph	O′	4	80.1	81.4	73.7	81.8	83.5	77.8	72.7	73.6	70.6	71.8	72.6	75.1	71.4	71.9	73.8	1.33
Aggregate, 10-70 mph	O′	4	80.4	81.8	72.9	79.1	80.7	77.9	74.2	71.0	68.7	69.8	72.6	74.1	71.7	69.2	72.4	2.63
Aggregate	K′	3	81.5	83.5	77.2	83.3	89.8	83.2	74.0	78.5	71.8	76.0	73.2	80.0	75.0	73.8	79.3	2.35
Aggregate	R	5	80.9	79.9	74.1	80.3	77.9	77.8	72.6	72.8	70.5	73.8	72.8	76.1	74.7	72.4	74.9	1.63
Integrated knock intensity	T	3	80.8	82.7	74.4	79.6	83.4	78.2	72.6	75.7	72.1	73.5	72.6	77.0	74.4	73.0	75.4	1.07
Knock intensity, 20 mph	Q	3	83.0	85.0	....	85.0	89.0	79.0	73.0	77.0	73.0	73.0	73.0	75.0	73.0	75.0	75.0	....
Knock intensity, 40 mph	Q	3	81.0	83.0	....	79.0	83.0	79.0	75.0	73.0	69.0	75.0	75.0	81.0	73.0	73.0	75.0	....
Knock intensity, 60 mph	Q	3	79.0	....	....	75.0	73.0	75.0	79.0	71.0	69.0	73.0	79.0	81.0	75.0	69.0	77.0	....
Aggregate grand average	O″	4, 2	79.3	80.5	73.1	80.6	81.9	77.4	72.0	72.5	69.6	71.4	71.3	74.2	71.5	70.9	72.8	1.86
Borderline	K″	3	80.0	82.0	72.3	78.0	78.7	77.3	68.7	72.7	70.3	72.3	68.0	75.7	72.0	72.7	73.0	2.20
CFR method, average	..	..	79.7	81.2	74.4	83.0	84.5	80.4	71.0	74.8	71.7	73.9	71.5	76.4	73.3	73.4	75.7	....
CFR method, high rating	..	..	82.0	83.5	77.3	85.0	90.7	83.3	73.3	81.0	74.8	76.7	73.3	80.0	74.7	75.8	80.0	....
CFR method, low rating	..	..	77.8	78.6	71.9	79.3	80.5	75.3	69.5	68.7	68.1	72.0	69.3	73.8	71.7	69.8	73.3	....
CFR method, spread	..	..	4.2	4.9	5.4	5.7	10.2	8.0	3.8	12.3	6.7	4.7	4.0	6.2	3.0	6.0	6.7	....
All methods, high rating	..	..	83.0	85.0	77.3	85.0	90.7	83.2	79.0	81.0	74.8	76.7	79.0	81.0	75.0	76.4	80.0	....
All methods, low rating	..	..	77.8	78.6	68.7	75.0	73.0	75.0	68.7	68.7	66.9	68.7	68.0	73.8	70.3	69.2	72.1	....
All methods, spread	..	..	5.2	6.4	8.6	10.0	17.7	8.2	10.3	12.3	7.9	8.0	11.0	7.2	4.7	7.2	7.9	....
ASTM octane No.	..	..	81.1	82.6	73.5	77.8	82.5	75.9	76.5	71.2	69.5	72.7	75.4	76.7	74.0	71.1	74.3	....
Research 1939 octane No.	..	..	82.2	84.2	79.2	86.3	94.4	83.2	76.9	82.9	76.4	78.8	75.3	82.1	79.2	79.2	80.2	....

Army, and to the principal manufacturers of ignition equipment and carburetors for passenger-car engines.

The following gasolines, representing a number of fuel types, were used in the tests:

Straight-run + catalytically cracked
California straight-run
Mid Continent straight-run + cracked
Mid Continent straight-run + cracked
Catalytically cracked
Highly olefinic polymer
Mixed crude, highly aromatic
Mid Continent straight-run + cracked reformed
Mid Continent cracked + straight-run
Benzol blend, 40 percent benzol
Two special blends of olefinic + paraffinic fuels
Natural gasoline
Mid Continent cracked
California cracked
California straight-run + cracked
Paraffinic straight-run
Mid Continent straight-run + cracked
Mid Continent straight-run + cracked
Mid Continent straight-run
71 octane No. reference fuel (A6 + C12)
80 octane No. reference fuel (C12 + F3)
Mid Continent straight-run + alkylate

A summary of the inspection data for these fuels is given in Table 3.

The test cars are listed in Table 4.

In selecting these cars an attempt was made to obtain a wide representation among 1940 and 1941 models, including from three to four different units of each make in the low-price group.

Approach to the Problem

The tests conducted in Part I indicated the need for new techniques by means of which more complete and more reliable information relative to fuel-knock characteristics in service can be obtained in a practical way by one laboratory without the necessity of using a large number of test cars in order to obtain sufficient data to be significant. One of the most important factors affecting knock characteristics, which was not taken into account by the earlier procedure, is engine speed.[2] As the engine speed at which a given fuel will knock in a given engine largely is determined by ignition timing, the problem appeared to resolve itself into a study of the relationship between ignition timing, engine speed, and knocking tendency.

One of the most practical means of examining this relationship appeared to be that first suggested by Greenshields and Hebl in 1937,[3] and later further developed and proposed as a road-test technique by Drinkard and Macauley in 1938.[4] Accordingly, the group participating in the centralized tests began by thoroughly testing this general method of approach in a wide variety of cars and, except for minor variations, ultimately adopted this as one road-test procedure for obtaining basic information from which a number of important relationships between any given fuel and engine can be determined.

In order that the concepts involved in this new method of approach to the detonation problem may be understood readily, a series of four illustrative diagrams has been prepared. These diagrams represent typical relationships between ignition timing, engine speed, power output, and fuel-knocking tendency, but do not represent any particular engine. They have been somewhat simplified and drawn for illustrative purposes only.

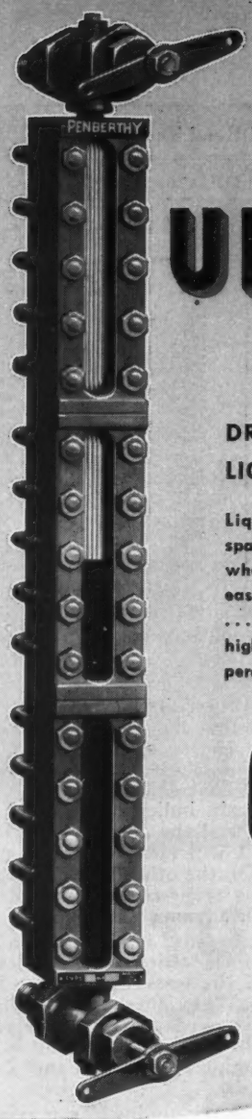
The relationship between ignition timing for maximum power and engine speed is a fundamental one, and is illustrated by curve **A** in Figure 1. The position of this curve varies from one engine to another, and depends upon such

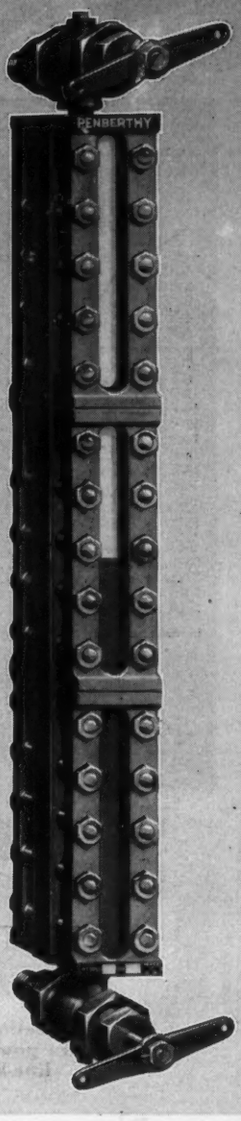
TABLE 2

Comparison of Road Knock Ratings Reported by Laboratory F, on 1 Fuel (32R) in 18 Different Units of Low-Price Cars

CAR MAKE	Road Rating (Equivalent ASTM Octane Number)
1939 A	77
1939 A	70
1939 A	73
1940 A	75
1940 A	77
1940 A	75
1939 B	75
1939 B	73
1939 B	77
1940 B	71
1940 B	74
1940 B	72
1939 C	71
1939 C	71
1939 C	69
1940 C	73
1940 C	75
1940 C	71
Average	73.3

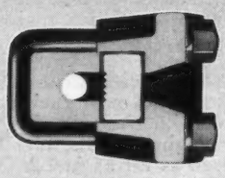
QUALITY UNCOMPROMISED





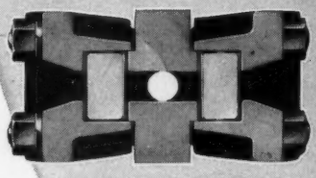
PENBERTHY
Reflex
DROP FORGED STEEL
LIQUID LEVEL GAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.

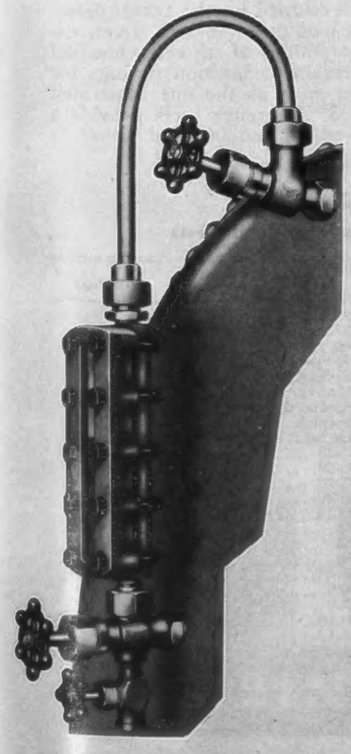


PENBERTHY
Transparent
DROP FORGED STEEL
LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . similar to Reflex types.



Penberthy Liquid Level Gages



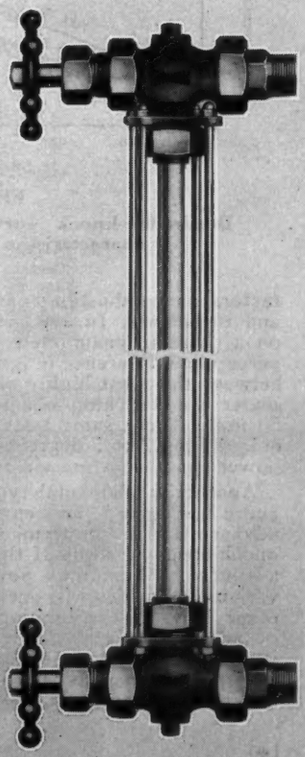
ALL PENBERTHY GAGES
CONFORM WITH A. P. I.—A. S. M. E. REQUIREMENTS

PENBERTHY
Reflex
WATER GAGE SET

Water shows black—steam shows white. U-bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler.

PENBERTHY
DROP FORGED STEEL
LIQUID LEVEL GAGES

Made of Chromium-molybdenum alloy temperature-resisting steel, extra heavy throughout. Stainless steel trimmed. Tubular glass type gages also available in various other metals suitable for practically all conditions.



PENBERTHY INJECTOR CO.

DETROIT, MICHIGAN ○ Canadian Plant: Windsor, Ontario

PENBERTHY PRODUCTS

TABLE 3

Summary of Inspection Data on Test Fuels Used in the 1940 CFR Centralized Road Tests

FUEL No.	OCTANE NUMBER			Lead Content (Milliliters of TEL † Per Gallon)	Reid Vapor Pressure (PSI)	Gravity (Deg. API)	ASTM DISTILLATION, IN °F.				
	ASTM *	Research 1939 *	Research Minus ASTM				Initial Boiling Point	10-Percent Point	50-Percent Point	90-Percent Point	End Point
1-B	65.0	65.1	0.1	0.8	8.3	62.8	95	146	233	350	395
2-B	64.9	68.7	3.8	0.0	9.6	62.5	91	136	228	341	412
3-B	71.0	73.4	2.4	0.0	6.1	64.0	119	163	208	290	365
4-B	74.9	73.9	—1.0	1.4	7.3	61.3	104	157	235	323	366
5-B	76.3	76.5	0.2	0.8	7.4	72.8	114	140	167	205	255
6-B	69.2	77.1	7.9	0.0	7.6	57.1	95	151	255	343	387
7-B	71.1	79.5	8.4	0.0	9.2	58.9	90	131	234	361	414
8-B	72.1	77.3	5.2	1.5	8.6	60.5	95	143	246	349	397
9-B	71.0	77.6	6.6	0.6	6.8	58.7	105	151	244	348	424
10-B	70.6	83.0	12.4	0.0	9.0	58.8	93	129	227	369	419
11-B	71.6	78.3	6.7	1.3	8.4	60.2	95	138	231	347	397
12-B	70.4	75.5	5.1	0.0	4.5	45.8	135	173	209	373	414
13-B	73.4	79.9	6.5	0.3	8.7	58.4	89	137	255	363	397
14-B	75.6	81.7	6.1	1.7	9.4	62.8	90	133	224	340	387
15-B	80.1	81.2	1.1	2.0	8.0	59.8	95	148	239	325	377
16-B	80.8	81.5	0.7	0.0	6.7	68.6	107	156	206	265	383
17-B	80.0	83.2	3.2	0.0	5.8	65.8	117	160	199	230	288
18-B	75.2	83.2	8.0	0.0	8.7	53.7	94	147	244	355	298
19-B	76.5	86.3	9.8	0.0	10.7	55.9	90	127	267	384	412
20-B	81.7	95.0	3.3	0.0	9.0	56.1	97	143	232	338	404
21-B	82.0	83.8	1.8	2.9	9.6	65.0	95	136	211	286	337
22-B	81.7	93.8	12.1	0.0	10.7	69.1	88	117	197	351	374
23-B	85.0	97.0	12.0	0.8	10.7	69.1	88	117	197	351	374

* Average of three engines. † Tetraethyl lead. **Note:** All data are as of November 14, 1940.

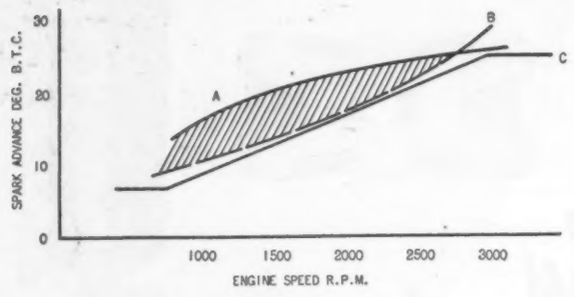


FIGURE 1

Typical relationship between ignition timing for maximum power, distributor advance, and borderline-knock curve for one fuel.

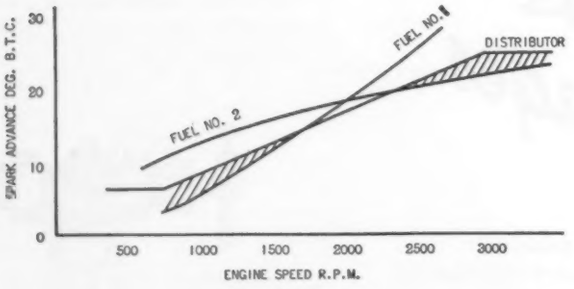


FIGURE 2

Borderline-knock curves showing distinguishing characteristics of different fuels.

factors as combustion-chamber shape, spark-plug location, and turbulence. In any given engine, however, tests made on a chassis dynamometer at San Bernardino indicated no perceptible difference in ignition timing for maximum power between the most highly olefine fuel and technical *iso*octane under non-knocking conditions at speeds between 10 and 50 mph. These same tests indicated that pure benzene required from 2 to 5 degrees less spark advance for maximum power than the aforesaid fuels.

Another fundamental type of curve is that illustrated by curve **B**, Figure 1. This curve represents the maximum spark advance which is permissible with a particular fuel for knock-free operation. If the engine is operated at the spark advance for maximum power with this fuel, detonation of various intensities will occur within the shaded area. On the other hand, if the ignition timing is controlled by means of an automatic device to conform with curve **C**, there would be no detonation at any speed. All this, of course, is elementary and is well known.

What is not so well known and widely appreciated is the type of information that is illustrated in Figure 2. In this figure are represented two fuels that have different characteristic responses to changes in engine speed and ignition timing. For purposes of illustration, these gasolines may be considered to have identical ASTM octane numbers. The curves representing each fuel again indicate the spark advance at which knocking begins; and the outstanding fact is that, at low engine speeds, fuel 1 will not permit the spark to be advanced as far as fuel 2. On the other hand, at higher engine speeds the relationship is reversed, and fuel 2 will not permit nearly so much spark advance as fuel 1.

This is an important concept, because it illustrates a significant characteristic of motor fuels which is not indicated, satisfactorily at least, by any of the tests which have been applied customarily in the past. When these characteristics are considered in relationship to the automatic spark advance given by a distributor as shown in Figure 2, the result is that fuel 1 will knock only at low engine speeds, and fuel 2 will knock only at high engine speeds.

Considered in relation to the spark timing for maximum power, these characteristics indicate that some types of fuels will permit the spark to be advanced closer to that required for maximum power than will others.

The technique that has been developed for the actual determination of these characteristics of gasoline in a given engine involves, first, the construction of a reference-fuel framework representing the permissible ignition timings for fuels of different octane number such as the one illustrated in the upper section of Figure 3. Reference fuels provide a common basis for comparison which can be used either to

TABLE 4

Cars Used in Centralized Road Tests

CAR	MODEL	Year
Buick	60	1941
Buick	40	1941
Buick	40	1940
Cadillac	60 Special	1939
Cadillac	60 Special	1941
Chevrolet	Master	1940
Chevrolet	Special de luxe	1941
Chevrolet	Special	1940
Chevrolet	De luxe	1941
*Chrysler 8	C-26	1941
*Chrysler 8	C-26	1940
*Chrysler 6	C-28	1941
*Chrysler 8	C-30	1941
Dodge	D-14	1940
Ford	85	1940
Ford	85	1940
Ford	85	1941
†Oldsmobile	L-40	1940
Packard 6	110	1940
Plymouth	P-9	1940
Plymouth	P-10	1940
Plymouth	P-12	1941
Pontiac 6	40-25	1940
Studebaker 6	Champion	1941

* Equipped with fluid drive.
† Equipped with hydramatic transmission.

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maintain a continuity over a period of time in one car or else to provide a common basis for comparisons made between different cars or between different laboratories. The reference fuels which were used in this investigation were the current standard reference fuels A-6, C-12, and F-3.

The broken lines in Figure 3 represent the ignition timings at which knocking begins with a series of reference fuels of graduated octane number, as indicated by the numbers attached to each curve. Superimposed on this framework are curves representing the characteristics shown by fuels 1 and 2 in Figure 2. In order to express the divergent characteris-

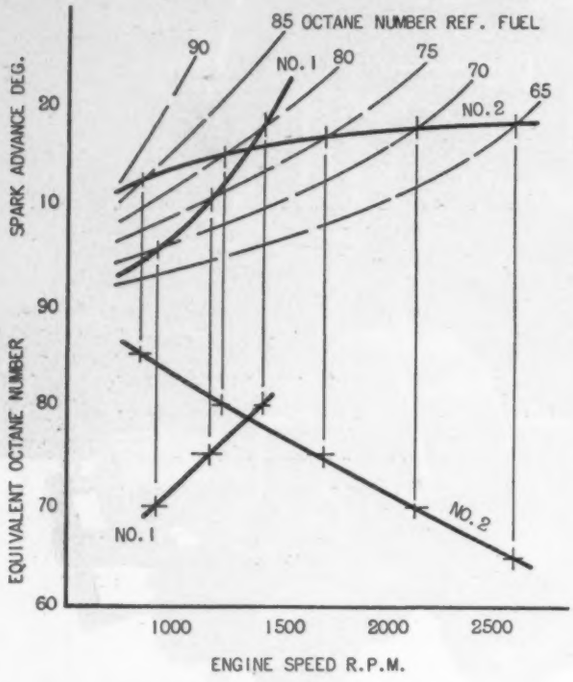


FIGURE 3

Determination of octane number vs. speed relationship.

tics of these two fuels in some terms which are independent of engine variables, the equivalent octane number may be determined either by interpolation with respect to the standard reference-fuel framework at several successive intervals in speed, or by a graphical construction based on the intercepts of the reference-fuel framework and the fuels under examination. (By equivalent octane number is meant the ASTM octane number of the reference fuel which is matched under the particular engine conditions in question.)

The graphical construction from which the equivalent octane number at various speeds can be determined is shown in Figure 3. The speed at which each fuel intercepts a reference-fuel line is determined, and then is plotted in the lower half of the figure against the corresponding octane number shown on the vertical axis.

Similarly, by interpolation at different speeds, at 1000 rpm. fuel 1 is equivalent to a reference fuel having an octane number of 71. At 1250 rmp the equivalent octane number is 76; and, at 1500 rpm, it is 81.

The curves representing fuels 1 and 2 in the lower section of Figure 3 clearly distinguish the different characteristics of these two fuels. This difference is expressed in terms of equivalent octane numbers, which have a more tangible meaning to the fuel technologist than an expression given in terms of spark advance. The latter is of more direct significance in connection with the utilization of any particular fuel in some particular engine.

The octane number vs. speed relationship shown in Figure 3 can be used in several ways. It can be used to distinguish between different fuel characteristics such as are shown by fuels 1 and 2 in the example shown. It may be used to distinguish a difference between different engines, or it may be used as an intermediate step in the determination of average fuel trends in a number of different engines. That is to say, by combining the curves representing the octane number vs. speed relationship for a single fuel in a number of different engines, it is possible to obtain a mean curve which is indicative of fuel characteristics based on results obtained in more than one engine.

The reference-fuel framework may be used further to express the fuel requirements of the engine, again in terms of the ASTM octane number at different speeds. Figure 4 illustrates the method for doing this. The distributor curve and the curve representing spark advance for maximum power are superimposed upon the reference-fuel framework. The intercepts made by the reference fuels and the distributor curve, or the curve representing spark advance for maximum power, then determine the octane requirement of the engine at the corresponding engine speeds. The octane numbers at the intercepts then may be plotted, as shown in the

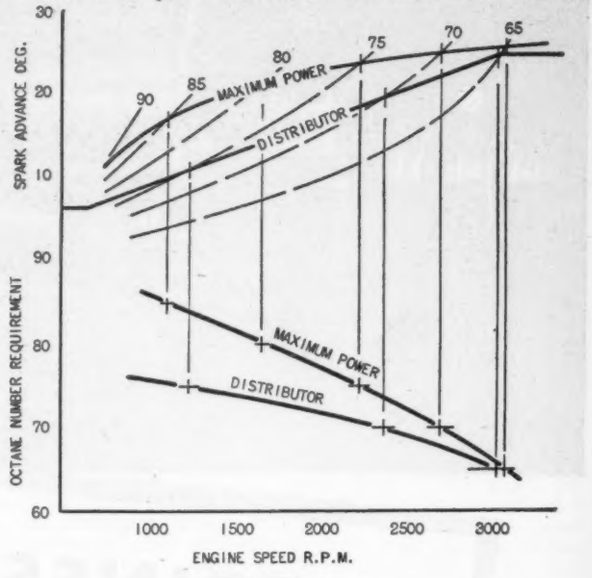


FIGURE 4

Determination of octane-number requirement.

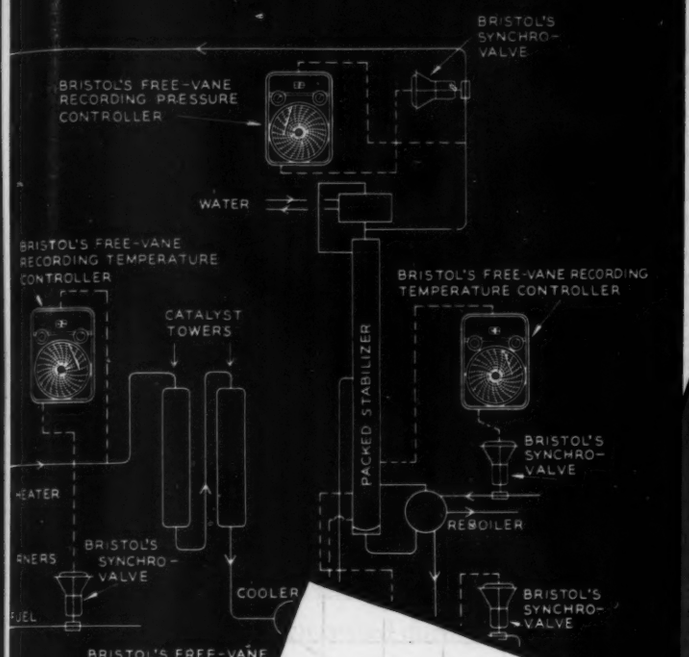
lower section of Figure 4, to produce a figure representing the octane requirement of the engine when operating either in accordance with a given distributor curve or a given spark timing for maximum power.

By superimposing the curves represented in the lower sections of Figures 3 and 4, it is possible to construct a diagram which is independent of ignition timing, and which will indicate whether a given fuel will knock and in what speed range in a given engine. Such a diagram is shown in Figure 5, and is useful in certain types of analysis.

Road-Test Procedures[5]

The San Bernardino data given in this report were obtained during wide-open throttle acceleration on a slight upgrade (2 to 3 percent) and at atmospheric temperatures between 60 and 75° F. Each car was fitted with a spark indicator either of the electronic-indicating type, or of the stroboscopic type with which the spark timing was read directly from the driving seat by observation of an illuminated scale attached to the flywheel. The connection for vacuum spark advance was disconnected from the distributor, and the automatic advance mechanism was locked. Provision then was made for manual advance of the spark from the driver's seat.

Spark-advance curves representing incipient or borderline detonation then were determined on reference fuels and on the 23 test fuels either in accordance with the "borderline procedure" described in the previous publications which have been referred to or by a modification of this procedure, called "modified borderline procedure," in which the spark was advanced manually during each acceleration in such a way as to keep the knock approximately constant at some light intensity. The spark advance at frequent intervals of speed then was observed and recorded during the accelerating period. To facilitate the rapid measurement of ignition timing during acceleration, readings of spark advance were taken by means of a calibrated dial attached to the shaft which was used to control the spark advance. Although the numerical values for spark advance that were recorded by the latter procedure differed from those obtained by the former or "borderline" procedure at corresponding speeds due to the difference in knock intensity that was used, the relative positions of different fuels were unaffected by the differences in the two methods. As a result, within the limits of knock intensity used in this work, knock intensity itself



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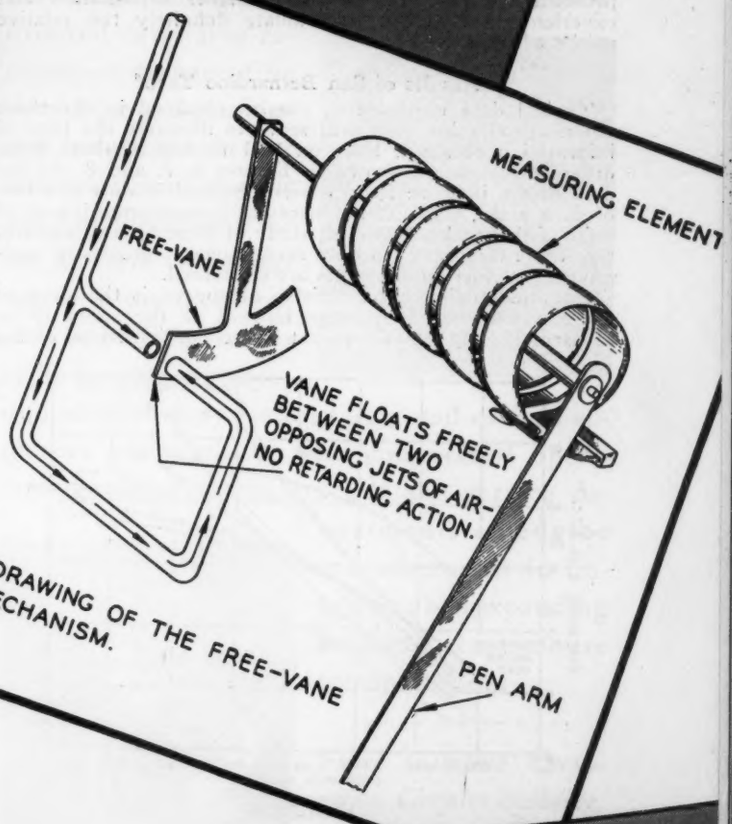

FIGURE 11
SIMPLIFIED DRAWING OF THE FREE-VANE CONTROL MECHANISM.

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had no appreciable effect on the relative standing of different fuels.

A certain amount of data was obtained using a "knock-intensity procedure," which was developed as a method of obtaining data on cars where extensive instrumentation was not feasible. Using this procedure, the anti-knock value of fuel throughout the speed range can be determined in terms of equivalent octane numbers by comparing the knock intensity of the fuel with that of reference fuels at several

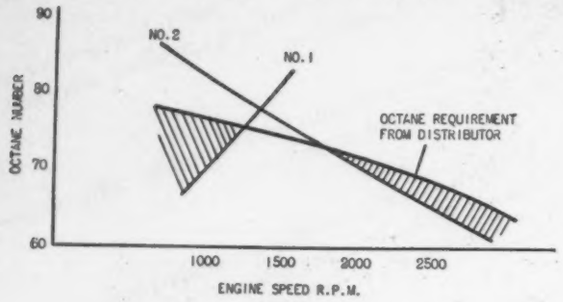


FIGURE 5

Comparison of equivalent octane-number curves with curve representing the octane requirement with a given distributor. The shaded area indicates where each fuel will knock.

speeds. Also an "octane-requirement procedure" has been developed for the purpose of determining octane requirement as related to speed in a large number of cars as found in service.

Present indications are that different procedures each adapted to the analysis of some particular phase of the problem are required, although further information and experience are needed to evaluate definitely the relative merits of each.

Results of San Bernardino Tests[6]

Typical data representing results, obtained in the three volume-production cars, will serve to illustrate the type of information obtained. Data on 1941 models of these three different makes are shown in Figures 6, 7, and 8. As the data shown in these figures were obtained in only one unit of each make, they are not necessarily representative of all units of that make. However, study of these figures indicates that these three engines have several characteristics in common where fuel requirements are concerned.

One outstanding characteristic, of course, is the slope of the reference-fuel framework upward as the speed is increased. Hardly less significant is the fan-like shape of the

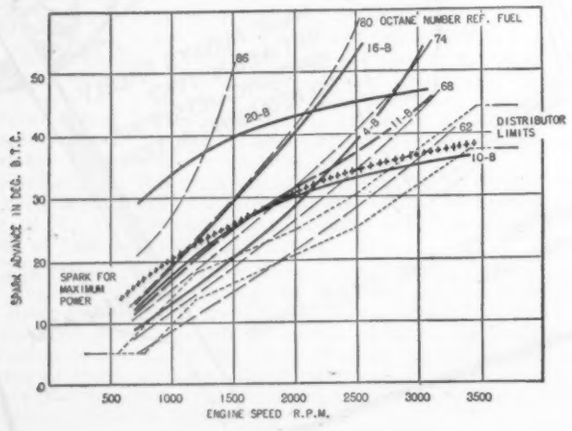


FIGURE 6

1941 car No. 7 after 8000 miles.

reference-fuel curves, tending to spread out at higher speeds. If the distributor happens to have been set so the engine knocks only at very low speed, a change of 1 or 2 degrees in initial spark timing will produce a much greater change in octane requirement, as expressed by reference fuels, than the same change in initial spark timing in a car in which the distributor happens to have been adjusted to produce knock at higher speeds. This same general pattern of behavior was shown by all 24 test cars.

Superimposed on Figure 6, 7, and 8 is the curve representing ignition timing for maximum power. In each case the road-octane requirement for maximum power, determined at the intercepts between the curves representing ignition timing for maximum power and reference-fuel borderline knock curves, respectively, was between 75 and 85 at speeds below 1000 rpm; whereas, at speeds above 2500 rpm, the road-octane requirement was from 60 to 68. This characteristic viz., a decreasing octane requirement with increasing engine speed, also was shown by all engines, although there were wide differences between different engines in octane requirement at any particular speed.

Different types of gasoline show common patterns of behavior in all three engines that are distinctly different from those of the reference fuels. Fuels 4-B, 10-B, and 11-B are three different types of gasoline of approximately 70 octane number, and fuels 16-B and 20-B are gasolines of approximately 81 octane number. Of the first three, fuels 4-B and 10-B represent somewhat extreme types of behavior. Fuel 11-B, which is a mixture of straight-run and cracked gasoline containing tetraethyl lead, has characteristics intermediate between those of 4-B and 10-B.

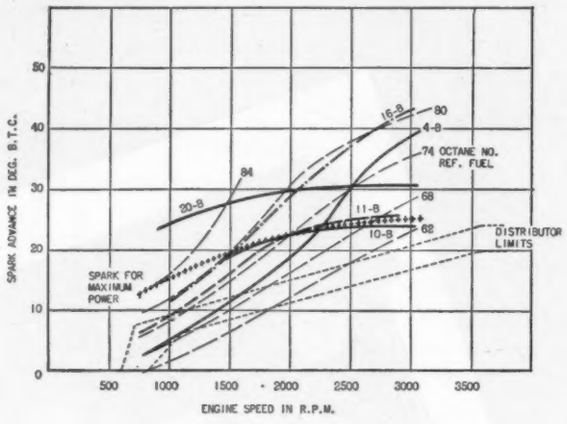


FIGURE 7

1941 car No. 11 after 10,000 miles.

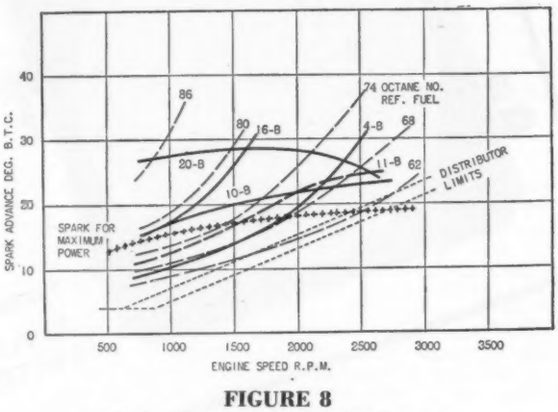


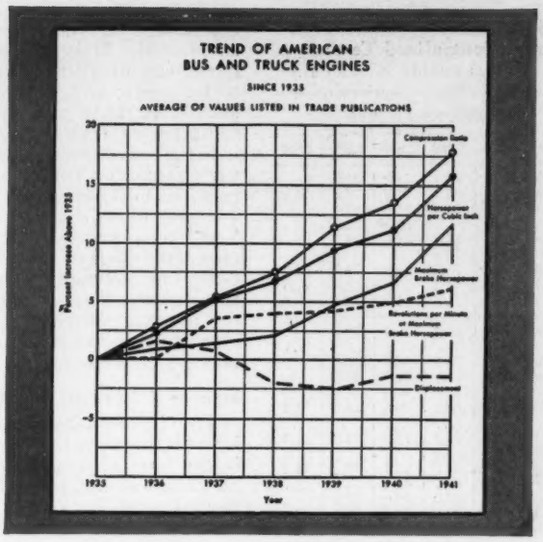
FIGURE 8

1941 car No. 24 after 2000 miles.

The curve for fuel 10-B is of particular interest because it so closely conforms to the curve representing ignition timing for maximum power in all three engines. This is a characteristic which may be of considerable significance from the standpoint of fuel utilization in engines and in the determination of future trends in fuel development. The reference-fuel data all indicate that, once the compression ratio has been fixed, straight-run gasolines knock more at low speeds than at high speeds, when the spark is advanced for maximum power. This same characteristic is also shown by most commercial fuels of which 11-B is one example, and it is partly for this reason that most distributors are designed to produce a retarded spark—relative to that for maximum power—at lower engine speeds and full throttle. On the other hand, the characteristics shown by fuel 10-B indicate that a more effective utilization of fuels may be possible through control of fuel characteristics along these lines. Of course, there are economic factors as well as the influence of combustion-chamber deposits and tendencies to pre-ignite, that have not been taken into consideration in this discussion,

octane number fuels. **2.** *In older equipment, by increasing engine compression ratios within permissible limits when the engines are overhauled or rebuilt.*

As far as new equipment is concerned, progressive bus and truck manufacturers are keeping pace with improvements in gasoline by producing engines designed to take advantage of higher anti-knock fuels. Chart at right shows how the efficiency of commercial vehicles has been increased during the past six years.



Influence of improved gasoline on future design

The trend is definitely toward engines of high compression ratios using higher anti-knock fuels. Commercial vehicle manufacturers are keeping the following points in mind when considering future models:

Larger, heavy-duty units are kept in service for at least five years. Models in current production, therefore, must not only use today's gasoline efficiently, but should be able to take advantage of the economies made possible by future gasoline improvements.

The trend toward more efficient engines using higher anti-knock gasoline is being accelerated as a result of limitations imposed upon commercial operators by taxation, legislation governing vehicle length and loading, and the initial cost of vehicles. Through increased power and earning capacity without increase in size, weight or cost of vehicles, operators can meet many of these limitations and at the same time lower their operating costs.

Developments along these lines are already under way. Many studies and experiments with possible future fuels and supercharged engines, or engines of much higher compression ratios than those now in use, are being conducted. However, the practical application of such engines and gasolines depends upon the solution of a host of related individual problems—not only of fuels and engine design, but of engine parts, materials and lubrication.

Cooperative research to solve common problems

We of the Ethyl Gasoline Corporation believe that these problems can best be solved by coordinated intensive research on the part of the petroleum and automotive industries. At our laboratories in Detroit and San Bernardino we are actively cooperating with the technical men in both fields. To make practical application of laboratory findings, our staff of field engineers are working with commercial operators, gasoline marketers and the service departments of engine manufacturers in improving and expanding commercial automotive transportation.

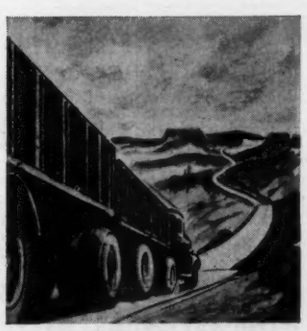


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TABLE 5
Road Octane-Number Summary—Centralized Tests
Road Octane Number of Fuel 4-B at Various Speeds in All Cars

	Car No.	Year	Number of Groups	ENGINE SPEED (RPM) 750	1,000	1,500	2,000	2,500	3,000
Low-Price Group.....	6	1941	1	71.0	71.0	72.0	72.0	71.0	....
	7	1941	2	71.0	69.5	70.5	71.5	73.5	74.5
	16	1940	1	69.0	71.0	71.0	71.0	72.0	....
	21	1940	1	69.0	69.0	....	69.0	73.0	....
	24	1941	2	66.0	67.5	68.0	68.5	70.5	....
	17	1940	1	70.0	68.0	70.0	....	....	....
	11	1941	2	68.0	68.0	70.5	70.5	74.5	77.0
	2	1940	2	70.5	70.5	70.5	70.5	71.0	71.0
	22	1940	1	65.0	68.0	71.0	74.0	76.0	77.0
Other Makes.	5	1941	2	71.0	69.0	70.5	70.0	70.5	....
	8	1940	..	....	....	....	....	....	....
	19	1940	2	69.0	68.0	72.0	70.0	70.5	....
	13	1940	1	66.0	69.0	71.0	72.0	75.0	....
	10	1940	1	....	71.0	73.0	72.0	....	....
	9	1941	3	65.0	66.0	68.5	70.5	73.0	73.5
	3	1940	..	....	....	....	....	....	....
	14	1940	1	72.0	72.0	74.0	74.0	74.0	77.0
	15	1940	1	68.0	68.0	73.0	....	....	....
	20	1941	2	67.0	68.0	72.0	72.5	70.0	75.0
	23	1939	2	65.0	68.0	68.0	69.0	71.0	....
	4	1941	2	69.0	69.5	69.0	70.0	70.0	....
	18 H.C. *	1941	1	67.0	71.0	70.0	72.0	72.0	77.0
	11 H.C. *	1941	..	69.5	69.0	68.5	68.5	68.5	68.5
Average all standard CR cars				68.4	69.0	70.8	71.0	72.2	75.0
Average 3, low-price group				68.8	69.2	70.4	70.9	72.7	74.9
Maximum spread, all standard CR cars				7.0	6.0	6.0	5.5	6.0	6.0
Maximum spread, low-price group				6.0	3.5	4.0	5.5	5.5	6.0

* H. C. indicates experimental high-compression cylinder head.

that would have to be taken into account in any such development.

Fuel 4-B, which is representative of certain types of fuels sold commercially, is of interest; because, even though the ASTM octane number of this fuel is from 4 to 5 units higher than that of 10-B, the latter fuel is better than 4-B by the equivalent of from 8 to 10 units in all 3 cars at speeds below 1000 rpm. Considered in relation to the distributor curves, 4-B would knock in cars 7 and 11, but not in car 24, with the timing shown. In the latter car, of course, the spark could be advanced for a gain in performance and economy.

Fuels 16-B and 20-B illustrate the same type of behavior among fuels having an ASTM octane number of about 81. In all three cars the anti-knock value of fuel 20-B at engine speeds between 2500 and 3000 rpm was lower than that of 4-B, and was even comparable with that of 11-B. In a car in which the distributor advance produced knock at these speeds, fuel 20-B, therefore, would be rated lower than 4-B, and perhaps equal to 11-B by the CFR road-test procedure used heretofore. Such a car would be car 24 with the initial spark advanced about 6 degrees.

All of these fuels indicate the desirability of tailoring the distributor-advance curve to fit the fuel characteristics as far as possible. It is obvious, however, that no one distributor curve can fit all types of fuels. Some compromise will have to be made; and, in making this compromise, it will be desirable to have available information pertaining to representative current motor gasolines.

TABLE 6
Road Octane-Number Summary—Centralized Tests
Road Octane Number of Fuel 10-B at Various Speeds in All Cars

	Car No.	Year	Number of Groups	ENGINE SPEED (RPM) 750	1,000	1,500	2,000	2,500	3,000
Low-Price Group....	6	1941	1	78.0	77.0	75.0	71.0	65.0	63.0
	7	1941	2	77.5	77.5	76.5	73.0	67.0	63.0
	16	1940	1	76.0	72.0	75.0	74.0	68.0	65.0
	21	1940	1	81.0	79.0	75.0	74.0	71.0	64.0
	24	1941	2	78.5	78.0	75.5	70.5	66.0	....
	17	1940	1	80.0	79.0	76.0	70.0	....	62.0
	11	1941	2	....	....	79.0	64.0	67.5	63.5
	2	1940	2	79.5	76.5	74.0	71.5	70.5	68.0
	22	1940	1	78.0	78.0	76.0	69.0	67.0	67.0
Other Makes.	5	1941	2	77.0	73.0	72.5	71.0	68.0	....
	8	1940	1	70.0	74.0	71.0	68.0	65.0	....
	19	1940	2	72.5	73.5	76.0	71.5	68.0	62.5
	13	1940	1	76.0	77.0	75.0	72.0	67.0	61.0
	10	1940	1	....	75.0	72.0	69.0	66.0	61.0
	9	1941	3	76.0	76.0	74.5	70.5	66.0	62.5
	14	1940	1	77.0	78.0	76.0	71.0	68.0	65.0
	15	1940	1	72.0	74.0	75.0	70.0	67.0	64.0
	20	1941	2	80.0	78.0	76.5	71.0	65.5	60.5
	4	1941	2	76.5	76.5	74.5	72.5	69.5	....
	23	1939	1	77.0	77.0	77.0	75.0	72.0	....
	8 H.C.*	1940	1	74.0	76.0	76.0	75.0	74.0	....
	9 H.C.*	1941	1	77.0	77.0	77.0	76.0	73.0	72.0
	11 H.C.*	1941	2	77.0	76.0	75.5	75.0	73.0	71.0
	18 H.C.*	1941	1	74.0	75.0	74.0	73.0	72.0	67.0
Average all standard CR cars				76.8	74.9	75.3	71.3	67.8	63.8
Average low-price group				78.0	77.1	75.8	71.9	67.8	64.4
Maximum spread, all standard CR cars				9.0	7.0	8.0	7.0	7.0	7.5
Maximum spread, low-price group				5.0	7.0	5.0	5.0	4.0	6.0

* H.C. indicates experimental high-compression cylinder head.

Figure 3 shows how octane ratings for a given fuel at various speeds could be determined from the reference-fuel pattern. Following this procedure the octane ratings of fuels 4-B and 10-B in different cars have been tabulated in Tables 5 and 6, respectively. These tables show that the distinctive characteristics of each fuel were shown consistently in all cars. The average values for all cars at each speed are tabulated at the foot of the tables, and may be compared with the average values for the low-price cars which are shown also. Average octane number vs. speed data for all fuels in all cars is summarized in Table 7.

Use of a Limited Number of Cars for Evaluation of Fuels

The information represented in Table 7 is of particular interest, because it indicates that the average ratings obtained in the low-price cars agreed well with the average ratings in all cars, and suggests the possibility of using a limited number of cars for evaluation of experimental or commercial fuels. It must be emphasized that three such cars will not necessarily show all the variations that all cars will show, although they may indicate reliably the trend.

Spark Advance and Compression Ratio

In order to evaluate fuels of high anti-knock quality, it often has been the practice to advance the ignition timing beyond that for maximum power to produce knock. However, the validity of knock ratings obtained under such conditions always has been open to question. The high-compression cylinder heads which were available for use in these road tests made it possible to obtain a direct comparison, in some cars, between ratings obtained in engines having standard compression and over-advanced ignition timing, with ratings obtained in the same engines with higher compression ratio and correspondingly less advanced ignition timings.

The results of this comparison are shown in Figure 9. At low engine speeds a change in compression ratio, accompanied by a corresponding change in ignition timing, had no appreciable effect upon road ratings. At high engine speeds, however, the fuel ratings were altered materially by changes in compression ratio, "sensitive" fuels being affected most.

It is concluded, therefore, that, although the performance of a fuel of high anti-knock value can be evaluated by over-advancing the ignition timing, the rating obtained in this way is not necessarily indicative of the performance of such a fuel in an engine designed to utilize the fuel effectively.

Application of New Concepts

There are several ways in which the octane-number-speed relationship illustrated in Figure 3 may be applied in fuel development and in the interpretation of fuel characteristics. The octane-number-speed relationship in itself is a useful means of distinguishing certain fuel characteristics, and in Figure 5 it is shown how this relationship could be combined with the octane requirement over the speed range in a given car to indicate the knocking tendency of a given fuel in a given car.

The indications are that this principle might be extended to provide statistical information on a large number of cars representative of cars in actual service, if there are available sufficient data on the octane requirements of these cars over a reasonable range of engine speeds. To illustrate how this might be accomplished, an analysis was made of the octane requirements of 19 cars used in the San Bernardino tests, having standard compression ratios.

The octane requirements at each speed were determined by the procedure illustrated in Figure 4, using distributor-advance curves corresponding to the high limit specified by the manufacturer. These octane-requirement data then were combined to form distribution curves showing the fraction of the total number of cars requiring fuels of various octane numbers at each engine speed over the range of speeds between 750 and 3000 rpm. This information is shown in Figure 10.

The relationship between fuel characteristics and car octane requirements on a statistical basis then is shown by comparing octane-number-speed curves with the octane-requirement framework shown in Figure 10. This is illustrated in Figure 11, in which the average octane-number-speed curves for three fuels, 4-B, 10-B, and 11-B, taken from Table 7 have been superimposed on the octane-requirement curves shown in Figure 10.

From this figure it is possible to determine the relative

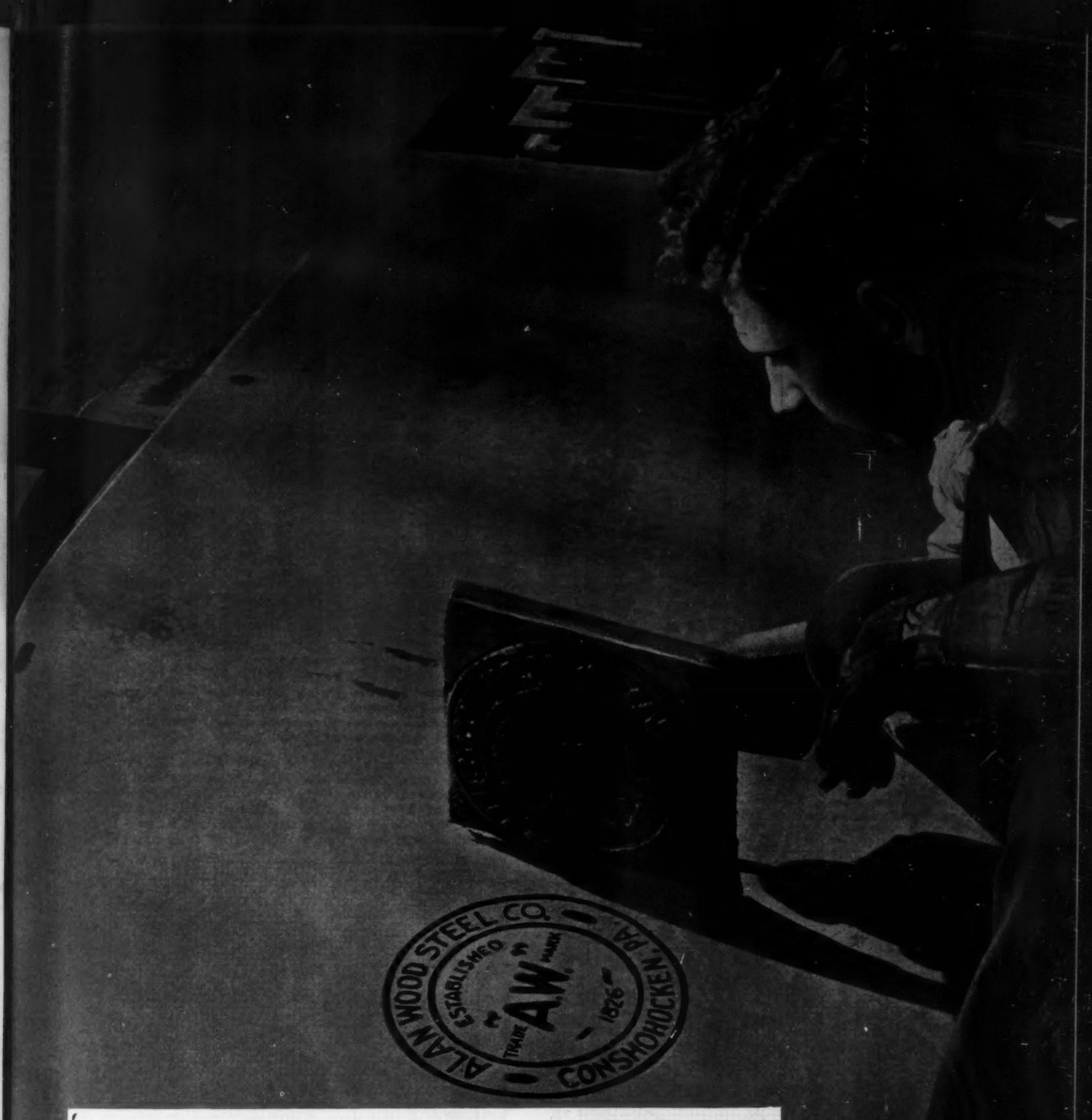

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TABLE 7
Comparison of Ratings of All Fuels in All Cars with Ratings of All Fuels in Three Low-Priced Cars of Different Makes.
(Expressed in Terms of the ASTM Octane Number of the Equivalent Reference-Fuel Blends)

Fuel No.	ENGINE SPEED (RPM) 750	1,000	1,500	2,000	2,500	3,000
*4-B	68.6	68.9	70.6	70.8	72.0	75.0
†4-B	68.8	69.2	69.5	69.7	70.0	....
*10-B	76.8	74.9	75.3	71.3	67.8	63.8
†10-B	76.7	....	76.5	72.2	67.2	63.5
*11-B	72.5	73.0	73.1	71.3	69.5	67.0
†11-B	72.8	73.7	74.5	72.0	68.3	67.2
*1-B	61.0	61.4	62.0	62.8	63.6	63.0
†1-B	60.3	61.0	61.2	62.5	62.3	62.8
*2-B	64.0	64.0	64.5	64.5	63.5	62.2
†2-B	65.2	64.5	64.5	65.0	63.3	62.7
*3-B	70.3	69.9	70.2	70.4	70.5	70.6
†3-B	70.5	69.7	69.7	70.2	69.7	70.0
*5-B	69.9	69.8	70.3	70.8	73.9	76.9
†5-B	69.0	70.3	69.7	70.5	75.0	....
*6-B	71.1	71.7	71.7	69.9	67.4	64.7
†6-B	72.3	72.7	72.8	70.2	65.7	64.2
*7-B	74.0	73.9	73.1	70.5	67.9	64.5
†7-B	75.5	76.0	74.8	68.5	67.7	65.7
*8-B	71.5	72.6	72.6	71.4	69.5	67.6
†8-B	70.8	71.8	72.5	71.5	68.0	67.2
*9-B	72.5	73.0	73.3	71.2	69.4	66.4
†9-B	71.2	72.3	73.8	72.2	68.2	66.5
*12-B	79.0	76.6	74.7	71.2	67.6	66.0
†12-B	82.5	79.5	76.3	73.2	67.2	65.7
*13-B	74.4	74.9	74.1	72.4	70.4	68.3
†13-B	76.5	77.0	75.8	72.8	69.5	68.3
*14-B	75.9	76.1	76.0	74.7	72.8	72.0
†14-B	77.5	77.3	76.3	74.7	71.3	70.5
*15-B	79.1	79.7	79.6	79.6	81.4	81.5
†15-B	79.5	80.0	80.0	79.7	81.0	81.5
*16-B	78.8	79.0	78.6	79.0	80.0	80.5
†16-B	79.0	79.3	79.0	78.8	79.5	80.5
*17-B	79.2	79.2	79.7	79.6	79.1	78.4
†17-B	79.5	79.3	80.0	80.2	79.7	78.5
*18-B	80.0	79.4	78.4	75.5	73.2	71.7
†18-B	79.5	80.3	79.5	76.3	74.7	71.2
*19-B	82.6	83.0	79.5	75.9	72.5	69.8
†19-B	83.3	83.8	80.5	76.3	72.5	69.7
*20-B	88.4	86.8	80.8	72.0	73.2	70.3
†20-B	89.0	86.7	82.5	79.5	75.0	69.8
*21-B	81.5	82.0	82.2	81.8	84.6	85.5
†21-B	82.2	81.8	83.0	82.5	85.0	86.0
*22-B	88.5	88.0	82.6	78.4	76.3	74.6
†22-B	89.0	88.5	84.2	80.5	78.0	74.5
*23-B	91.0	89.5	86.0	84.5	84.0	83.0
†23-B	No data, too high to rate					

* Average of all available data in all standard cars.
† Average of ratings in cars 6, 11 and 24.

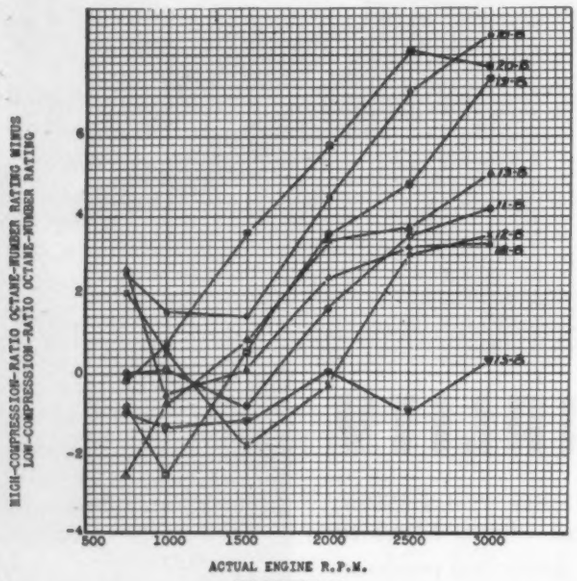

FIGURE 9
Effect of change in compression ratio on road anti-knock value.

CAR No.	DATA OBTAINED IN Low Compression Ratio	High Compression Ratio
8	6.1	8.1
9	6.8	8.45
11	6.7	8.2
13	7.1	8.8

performance of each fuel in a large number of cars with respect to actual car requirements and, further, to distinguish between the relative performance of fuels at different speeds. For example, according to this information, fuel 10-B would be free from knock in from 80 to 90 percent of all the cars represented at speeds between 750 and 3000 rpm. Fuel 4-B, on the other hand, would be free from knock in only 40 to

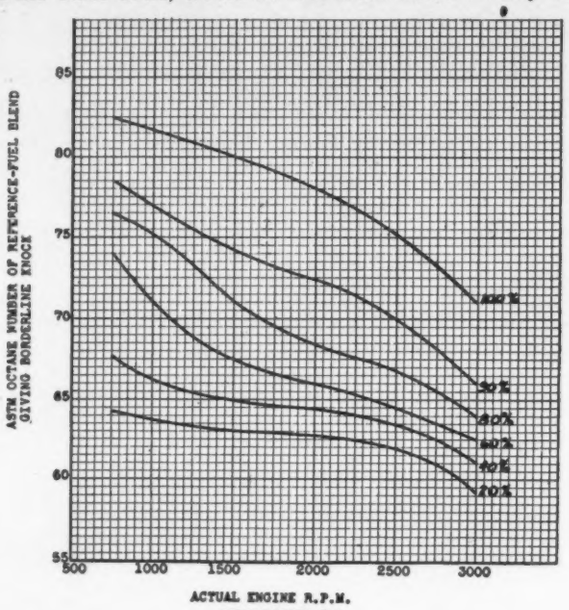

FIGURE 10
Percentage of cars giving borderline knock on reference-fuel blends (data based on 19 cars having standard compression ratio, using upper limit of manufacturer's distributor curve).

50 percent of the cars at engine speeds below 1000 rpm—although, at engine speeds above 2000 rpm, this fuel would knock in fewer cars than 10-B, and would not knock in any of the cars at 3000 rpm. Fuel 11-B represents a gasoline having characteristics intermediate between 4-B and 10-B, and would be free from knock in from 50 to 80 percent of

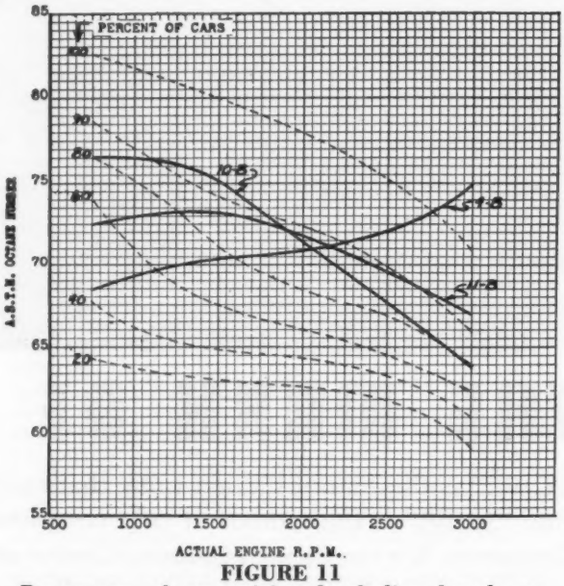

FIGURE 11
Percentage of cars giving borderline knock on reference-fuel blends and three test fuels of varying type (reference-fuel data based on 19 cars of standard compression ratio; data for fuels 4-B, 10-B, and 11-B are based on ratings in 15 to 21 cars).

the cars, the degree of freedom from knock being somewhat less dependent upon engine speed than that of 4-B.

Application to Engine Design

The application of these new concepts to engine design depends somewhat upon the degree to which the type of

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reference-fuel frameworks shown in Figures 6, 7, and 8 can be reduced to representative and reproducible data which can be used as a basis for engineering development. If such information can be obtained which will be truly representative of a given engine design, it will be possible to use this information as a guide in the correlation of engine design with the characteristics of available fuels to an extent which

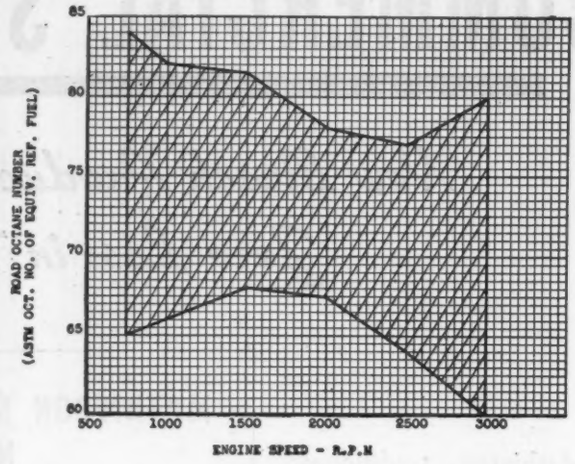

FIGURE 12

Spread in road ratings of 11 fuels obtained in 19 cars—ASTM octane numbers from 69.2 to 26.3; 1939 research octane numbers from 73.9 to 83.2.

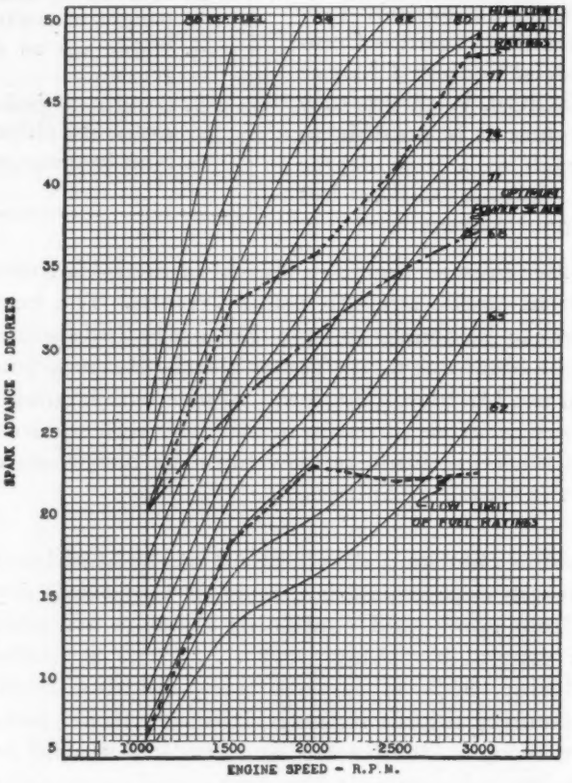

FIGURE 13

Actual reference-fuel frameworks for one make of car and effective road-octane limits for Gasolines shown in Figure 12.

heretofore has not been possible. Such correlation, however, is contingent upon the availability of corresponding information on the characteristics of current motor gasolines. If the pattern of behavior of gasolines can be determined with reasonable certainty, then it may be possible to obtain a more satisfactory relationship between engine design and fuel characteristics.

At the present time there is a wide spread in characacteristics among commercial gasolines which makes it difficult to go any further than to make a rough compromise between engine design and fuel characteristics. For example, Figure

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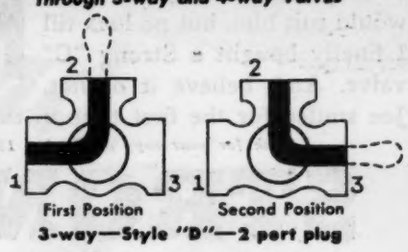
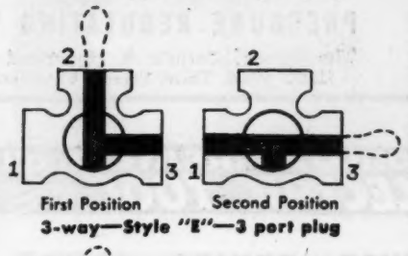
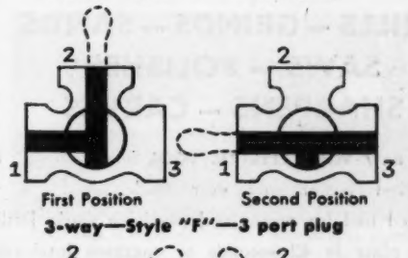


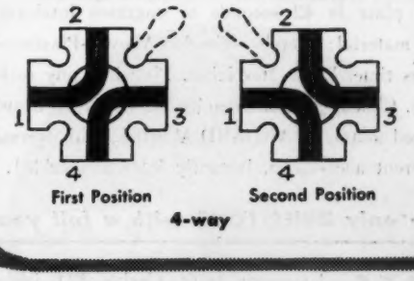
3-way—Style "D"—2 port plug



3-way—Style "E"—3 port plug



3-way—Style "F"—3 port plug



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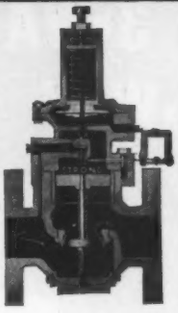

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12 shows the spread in the octane-number-speed relationship for 11 different fuels used in the San Bernardino tests having ASTM octane numbers between 69 and 76. In road tests these fuels varied over a range of from 65 to 84 octane number at 750 rpm, and from 60 to 80 octane number at 3000 rpm.

What this variation in characteristics means in terms of engine design is shown in Figure 13, in which are represented the actual reference-fuel frameworks for one make of car; and superimposed on these frameworks are the effective road octane limits for the gasolines shown in Figure 12. It is clear from this figure that a wide range in distributor-advance curves would be permissible within this range which would be entirely satisfactory for some fuels and unsatisfactory for others. For this reason, it is believed desirable to have available more definite information on the relative volumes of distribution of gasolines having various characteristics; and, according to present plans, the CFR Committee will obtain such information during the current year.

Outlook

It is believed that significant advances in understanding the relationships between fuels and engines have been brought about as a result of the 1940 cooperative road tests. However, the application of these relationships requires further experience with the procedures and additional data on commercial fuels and cars in normal service. To continue the work along these lines, the CFR Committee has outlined a program to be carried out in 1941. Reference-fuel frameworks are to be determined on a number of current

ORGANIZATIONS AND PERSONNEL PARTICIPATING IN CENTRALIZED ROAD TESTS AT SAN BERNARDINO, CALIFORNIA

Organization	Personnel
The Atlantic Refining Co.	F. C. Burk
	L. J. Test
Bendix-Stromberg Carburetor Co.	V. A. Smith
Carter Carburetor Co.	L. D. Boyce
Chrysler Corp.	W. E. Drinkard
Cities Service Co., Research Division	J. D. Morgan
	P. B. Levitt
	J. Oberhollenzer
	S. G. Wilson
Continental Motors Corp.	K. E. Chantry
Delco-Remy Division, General Motors Corp.	J. T. Fitzsimmons
Ethyl Gasoline Corp.	H. J. Gibson
	Gilbert Way
	T. H. Risk
General Motors Corp., Research Division and Proving ground	J. M. Campbell
	W. A. Snyder
General Petroleum Corp.	H. A. Mason
	J. M. Grandy
	J. D. Tobey
Gulf Research and Development Co.*	J. E. Taylor
National Bureau of Standards	C. S. Bruce
	O. C. Bridgeman
Phillips Petroleum Co.	H. M. Trimble
	K. C. Bottenberg
	F. E. Selin
The Pure Oil Co.	W. B. Ross
	Kenneth Boldt
Richfield Oil Corp.	L. J. Grunder
Shell Oil Co., Inc.	R. J. Greenshields
Shell Oil Co. of California	A. G. Marshall
	J. T. Ronan
	A. R. Isitt
Sinclair Refining Co.	L. E. Baker
	W. G. Ainsley
Society of Automotive Engineers	C. B. Veal
Socony-Vacuum Oil Co., Inc.	W. M. Holaday
	W. S. Mount
	T. A. Weir
Standard Oil Co. of California	J. R. MacGregor
	R. A. Walker
Standard Oil Co. (Indiana)	J. O. Eisinger
The Standard Oil Co. (Ohio)	R. I. Potter
	E. H. Scott
Standard Oil Development Co.	C. B. Kass
	V. F. Massa
Sun Oil Co.	J. G. Moxey, Jr.
The Texas Co.	W. N. Fenney
	E. L. Lattin
	L. A. Humphrey
Tide Water Associated Oil Co.	W. A. Heine
	G. M. Wheeler
Union Oil Co.	C. C. Moore
	M. S. Reynolds
	R. I. Stirton
Universal Oil Products Co.	J. S. Bogen
U. S. Army, Ordnance Department	T. H. Nixon
	G. H. Schoenbaum
Waukesha Motor Co.	A. W. Pope Jr.
Yale University	H. W. Best

* Gulf Oil Corporation contributed data to part I, only, of these tests.

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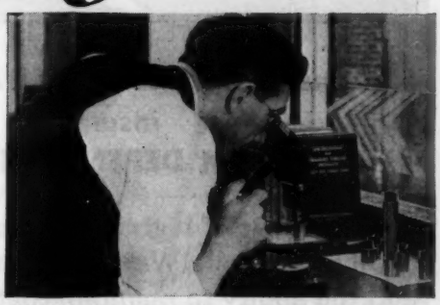

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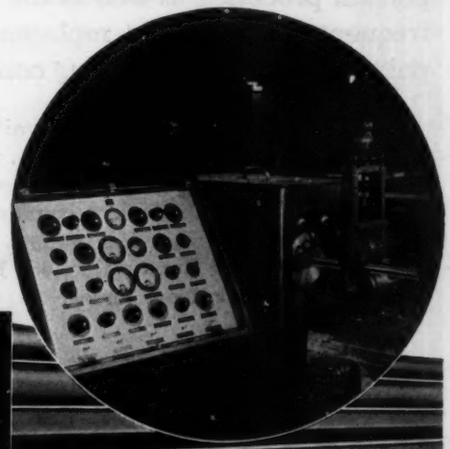
Each tube is inspected red hot, seconds after piercing.



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WESTON *ALL-METAL GAUGE TYPE* **THERMOMETERS**

passenger-car engines to provide engineering information on the degree of uniformity in fuel requirements, irrespective of variations caused by differences in distributor settings. In order to test the usefulness of control fuels in orienting individual laboratory test cars and relating them to a significant number of cars, four fuels representing several types of gasoline are to be exchanged among the cooperating laboratories. A survey of the road anti-knock performance of widely used commercial fuels in terms of road octane-number ratings over the speed range is to be made in a representative group of cars. The program also includes an octane-requirement survey to provide data from which a statistical study of the octane requirements over the speed range of popular cars as found in service can be made.

The new concepts of the anti-knock problem developed in 1940, supplemented with information from the 1941 cooperative program, should make it possible to adapt engines better to current fuel characteristics and modify fuel characteristics more effectively toward the requirements of current engines.

Acknowledgment

The Cooperative Fuel Research Committee is extremely grateful to the many men and to the organizations that have so generously supported this project. The men who participated in these tests have given freely of their time and energy in very phase of the work; and in supporting these men, the contributing organizations have supplied money, fuels, test cars, instrumentation, and every facility that has been needed.

BIBLIOGRAPHY

[1] (a) "Standard Engine for Fuel Tests," *SAE Journal* **24,** 212-13 (1929).

(b) "Tentative Recommended Practice for Conducting Anti-knock Tests," *SAE Journal* **29,** 164-65 (1931).

(c) C. B. Veal, H. W. Best, J. M. Campbell, and W. M. Holaday, "Anti-knock Research Coordinates Laboratory and Road Tests," *Trans. Soc. Automotive Engrs.* **28,** 105-20 (1933); *SAE Journal* **32,** 105-20 (1933).

(d) C. B. Veal, "CFR Committee Report on 1934 Detonation Road Tests," *Trans. Soc. Automotive Engrs.* **30,** 165-79 (1935); *SAE Journal* **36,** 165-79 (1935).

(e) A. E. Becker, "Effect of Test Conditions on Fuel Rating," *Trans. Soc. Automotive Engrs.* **33,** 63-72 (1938); *SAE Journal* **42,** 63-72 (1938).

(f) T. A. Boyd, "1937 Road Knock Tests," *Trans. Soc. Automotive Engrs.* **33,** 244-52 (1938); *SAE Journal* **42,** 244-52 (1938).

(g) J. R. Sabina "Correlation of Road and Laboratory Octane Numbers," *Trans. Soc. Automotive Engrs.* **33,** 416-20 (1938); *SAE Journal* **43,** 416-20 (1938).

(h) "CFR Research Method of Tests for Knock Characteristics of Motor Fuels," *Trans. Soc. Automotive Engrs.* **34,** 277-80 (1939); *SAE Journal* **44,** 277-80 (1939).

(i) H. L. Horning, "Standardizing of Anti-knock Testing," *Proc. API* **10 [III]** 32.7 (1929).

(j) T. A. Boyd, "Progress Toward a Uniform Method of Measuring Detonation," *Proc. API* **11 [III]** 38-45 (1930).

(k) T. A. Boyd, "The CRF Research Apparatus and Method for Knock Testing," *Proc. API* **12 [III]** 46-59 (1931).

(l) C. B. Veal, H. W. Best, J. M. Campbell, and W. M. Holaday, "Correlation of CFR Laboratory Knock Ratings with Behavior of Motor Fuels in Service," *Proc. API* **13 [III]** 139-53 (1932).

(m) C. B. Veal, "The 1934 Detonation Road Tests," *Proc. API* **15 [III]** 33-54 (1934).

(n) T. A. Boyd, "1934 Road Knock Tests," *Proc. API* **18 [III]** 98-112 (1937).

(o) A. E. Becker, "Effect of Test Conditions on Fuel Rating," *Proc. API* **18 [III]** 112-25 (1937).

[2] (a) C. B. Veal, "CFR Committee Report on 1934 Detonation Road Tests," *Trans. Soc. Automotive Engrs.* **30,** 165-79 (1935); *SAE Journal* **36,** 165-79 (1935).

(b) J. M. Campbell, W. G. Lovell, and T. A. Boyd, "Relative Knocking Characteristics of Motor Fuels in Service." *Trans. Soc. Automotive Engrs.* **32,** 144-50 (1937); *SAE Journal* **40,** 144-50 (1937).

[3] (a) Discussion by R. J. Greenshields and L. E. Hebl of paper "Additional Service Data on Effect of Ignition Timing," *Trans. Soc. Automative Engrs.* **32,** 148-50 (1937); *SAE Journal* **40,** 148-50 (1937).

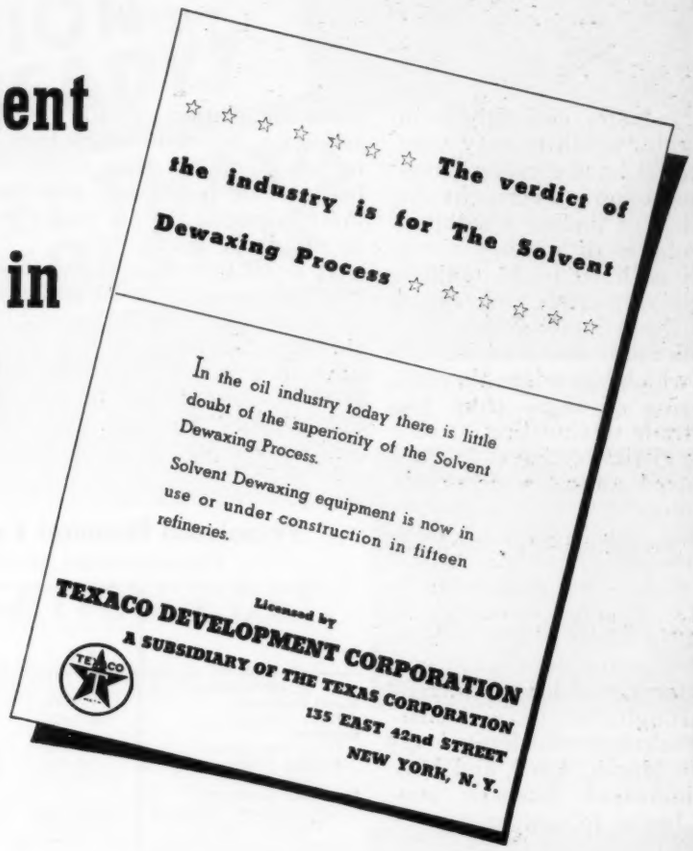
(b) L. E. Hebl and T. B. Rendel "Spark Timing—Its Relation to Road Octane Numbers and Performance," *Trans. Soc. Automotive Engrs.* **34,** 210-20 (1939); *SAE Journal* **44,** 210-20 (1939).

[4] W. E. Drinkard and J. B. Macauley, Jr., "Spark Advance and Octane Number," *Trans. Soc. Automotive Engrs.* **33,** 436-40 (1938); *SAE Journal* **43,** 436-40 (1938).

[5] Complete information regarding the road-test procedures may be obtained from C. B. Veal, secretary, Cooperative Fuel Research Committee, Society of Automotive Engineers, 29 W. 39th Street, New York.

[6] Final analysis of the data obtained in parts I and II of the 1940 CFR road tests was carried out by the Detonation Road-Test Analysis Group: R. J. Greenshields (leader), Shell Oil Co., Inc.; H. W. Best, Yale University; K. Boldt, The Pure Oil Co.; F. C. Burk, The Atlantic Refining Co.; J. M. Campbell, General Motors Corp.; W. E. Drinkard, Chrysler Corp.; H. J. Gibson, Ethyl Gasoline Corp.; C. B. Kass, Standard Oil Development Co.; W. S. Mount, Socony-Vacuum Oil Co., Inc.; J. G. Moxey, Sun Oil Co.; B. R. Siegel, Sinclair Refining Co.; and C. B. Veal, Society of Automotive Engineers.

This advertisement was published in 1937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Tanker Problem Overshadows Ordinary Economic Factors

L. J. LOGAN

THE oil industry currently is in a strange role, which nobody very far back could have foreseen, having had cast upon it overnight the responsibility of finding a solution to the problem of getting along henceforth with 50 to 75 tankers less in supplying crude and refined oils along the Atlantic Coast.

The difficulties involved in this situation, which has arisen through the diversion of ships from the domestic trade to shuttling service for Great Britain, have largely overshadowed all other economic considerations for the industry. And within the span of a few months, the industry has passed through these contrasting conditions: (1) a slow recovery—in most of 1940—from the ill effects of surplus gasoline, lubricants, and other products, which accumulated largely through loss of export business; (2) sharply accelerated recovery—in March, April, and May—when increased domestic consumption began to compensate for lost export business, and when the larger demand and better balancing of crude production and refinery runs with demand strengthened markets; (3) sudden dislocation of operations through the tanker situation, which threatens to necessitate industry-wide readjustments, from well to retail outlet, in holding down inconvenience to consumers and loss of business for the oil companies.

The oil industry this year has been confronted with the greatest consumer demand for its products ever experienced in its history, despite the fact that exports have dwindled to far less than half their pre-war proportions.

But upon the requisitioning of the tankers, the industry suddenly faced the problem of meeting this extraordinary demand without its normal tank ship facilities, which had been adequate but not excessive for prevailing and anticipated movements of oil.

The industry, therefore, now views statistics on large market demand with some misgivings instead of elation. Ready markets are quite desirable when they can be supplied. But they threaten to become an important problem if material difficulty is experienced in supplying them.

It is to be expected, of course, that any scarcity of oil which may arise on the Atlantic seaboard, through deficiency of tankers, will have its compensating effects. Unless the normal laws of economics are impeded, through government action, scarcity of oil on the East Coast would force prices up, and loss of volumes of business by the oil companies would be at least partially compensated by the higher prices.

However, the chief concern of the oil industry, probably, in the present disturbed situation, is the danger of protests from the consuming public over any increases in oil prices that may arise in consequence of the transportation difficulties.

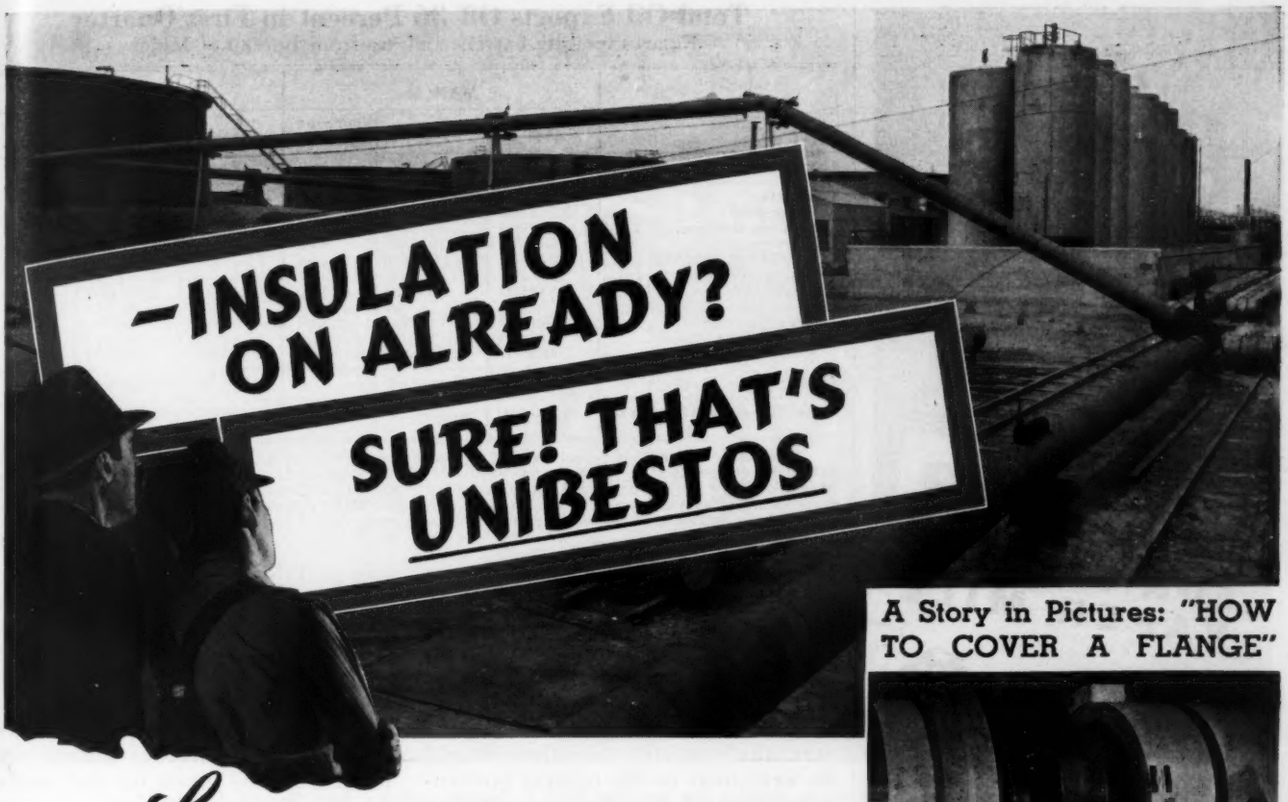
The oil industry could not be

Petroleum Demand Up 4.4 Percent in First 3 Months

Figures indicate barrels, and are from Bureau of Mines.

	MARCH			FIRST THREE MONTHS		
	1940	1941	Percent Change	1940	1941	Percent Change
SUMMARY—						
Total Demand	121,997,000	127,829,000	+ 4.8	355,821,000	367,341,000	+ 3.2
Daily Average	3,935,000	4,124,000	+ 4.8	3,910,000	4,082,000	+ 4.4
Exports:						
Crude Petroleum	4,046,000	1,988,000	— 50.9	11,575,000	5,017,000	— 56.7
Refined Products	7,583,000	5,414,000	— 28.6	20,074,000	15,135,000	— 24.6
Total Exports	11,629,000	7,402,000	— 36.3	31,649,000	20,152,000	— 36.3
Domestic Demand:						
Total Domestic Demand	110,368,000	120,427,000	+ 9.1	324,172,000	347,189,000	+ 7.1
Daily Average	3,560,000	3,885,000	+ 9.1	3,562,000	3,858,000	+ 8.3
TOTAL DEMAND FOR PRODUCTS—						
Motor Fuel:						
Domestic	44,607,000	48,606,000	+ 9.0	122,534,000	136,203,000	+ 11.2
Exports	2,265,000	2,044,000	— 9.8	6,442,000	5,454,000	— 15.3
Total	46,872,000	50,650,000	+ 8.1	128,976,000	141,657,000	+ 9.8
Aviation Gasoline:						
Domestic	457,000	547,000	+ 19.7	1,358,000	1,593,000	+ 17.3
Exports	336,000	[1]497,000	+ 47.9	793,000	1,292,000	+ 62.9
Total	793,000	1,044,000	+ 31.7	2,151,000	2,885,000	+ 34.1
Kerosene:						
Domestic	6,273,000	6,778,000	+ 8.1	20,178,000	21,031,000	+ 42.3
Exports	485,000	165,000	— 66.0	1,174,000	339,000	— 71.1
Total	6,758,000	6,943,000	+ 2.7	21,352,000	21,370,000	+ 0.1
Gas Oil and Distillate Fuels:						
Domestic	16,187,000	[2]19,753,000	+ 22.0	56,272,000	58,471,000	+ 3.9
Exports	2,318,000	[3]1,037,000	— 55.3	5,101,000	3,423,000	— 32.9
Total	18,505,000	20,790,000	+ 12.3	61,373,000	61,894,000	+ 0.8
Residual Fuel Oils:						
Domestic	31,188,000	[4]32,735,000	+ 5.0	90,784,0000	96,990,000	+ 6.8
Exports	932,000	[5]1,206,000	+ 29.4	2,840,000	3,183,000	+ 12.1
Total	32,120,000	33,941,000	+ 5.7	93,524,000	100,173,000	+ 7.1
Lubricants:						
Domestic	1,883,000	2,263,000	+ 20.2	5,459,000	6,428,000	+ 17.8
Exports	1,193,000	703,000	— 41.1	3,350,000	1,981,000	— 40.9
Total	3,076,000	2,966,000	— 3.6	8,809,000	8,409,000	— 4.5
Wax (thousands of pounds):						
Domestic	19,343	34,865	+ 80.2	71,558	103,426	+ 44.5
Exports	25,642	13,766	— 46.3	75,051	37,945	— 49.4
Total	44,985	48,631	+ 8.1	146,609	141,371	— 3.6
Coke (short tons):						
Domestic	119,900	114,500	— 4.5	383,400	428,600	+ 11.8
Exports	13,700	10,500	— 23.4	35,800	36,800	+ 2.8
Total	133,600	125,000	— 6.4	419,200	465,400	+ 11.0
Asphalt (short tons):						
Domestic	254,200	295,800	+ 16.4	547,000	734,100	+ 34.2
Exports	18,900	19,200	+ 1.6	62,300	54,500	— 12.5
Total	273,100	315,000	+ 15.3	609,300	788,600	+ 29.4
Road Oil:						
Domestic Demand	111,000	66,000	— 40.5	311,000	255,000	— 18.0
Miscellaneous:						
Domestic	123,000	311,000	+152.8	398,000	785,000	+ 97.2
Exports	126,000	53,000	— 57.9	377,000	137,000	— 63.7
Total	249,000	364,000	+ 46.2	775,000	922,000	+ 19.0

[1] Includes 54,000 barrels anti-knock compounds. [2] Includes 634,000 barrels bunker oil. [3] Includes 9,000 barrels exported from bond. [4] Includes 1,755,000 barrels bunker fuel oil. [5] Includes 36,000 barrels exported from bond.



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Ability to apply UNIBESTOS quickly and neatly over all kinds and shapes of pipe, fittings, vessels, and flat surfaces is a result of the distinctive physical features of the material itself. UNIBESTOS comes in a complete range of sizes, accurately dimensioned inside and out. It cuts and strips readily to make fitting up a simple job.

This is not the only place where UNIBESTOS excels! It takes hard knocks without damage. It is difficult to dent and it will not shatter. Vibration has no effect. Even when soaked, moisture can be steamed off repeatedly without damaging structure. No shrinkage, no sagging — ideal for outdoor or underground mains.

UNIBESTOS has higher thermal efficiency than the most commonly used insulations. Cost, including installation, often runs less. It is offered in a complete range of sizes: sectional insulation for all pipe diameters up to 36", thicknesses up to 5". Sheets up to 36"x 36"x5". Available in 750°F. or 1200°F. material, or any combination of the two in single layer construction for any intermediate temperature.

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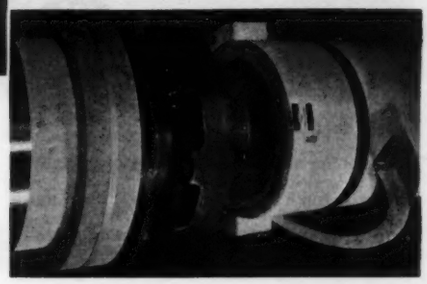
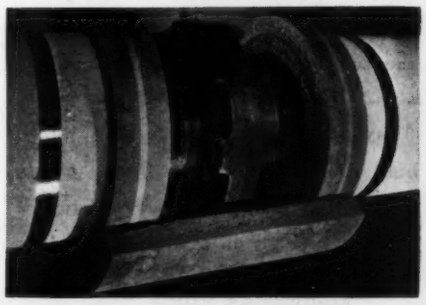
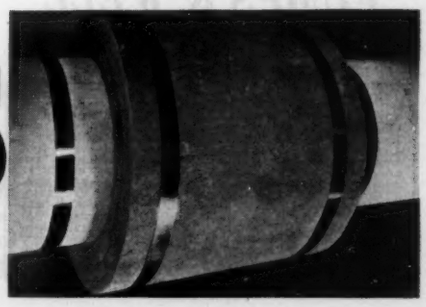


1. (ABOVE): Fitting two short collars over ends of pipe covering on each side of flange.



2. (ABOVE): Placing a long collar (also cut from standard UNIBESTOS) over the two short collars.

3. (BELOW): The complete covering. Smooth, neat, efficient, and readily removable.



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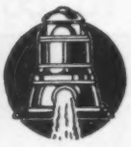

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Total Oil Exports Off 36 Percent in First Quarter

Figures indicate barrels, and are from Bureau of Mines.

ITEM	MARCH 1940	MARCH 1941	MARCH Percent Change	FIRST 3 MONTHS 1940	FIRST 3 MONTHS 1941	FIRST 3 MONTHS Percent Change
Crude Oil	4,046,000	1,988,000	— 50.9	11,575,000	5,017,000	— 56.7
Products:						
Motor Fuel	2,265,000	[1]2,044,000	— 9.7	6,442,000	5,454,000	— 15.3
Aviation Gasoline	[2]336,000	497,000	+ 47.9	793,000	1,292,000	+ 62.9
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Miscellaneous Oils	126,000	53,000	— 57.9	377,000	137,000	— 63.7
[6]Total Refined Products	7,583,000	[5]5,414,000	— 28.6	20,074,000	15,135,000	— 24.6
Total Crude and Products	11,629,000	7,402,000	— 36.3	31,649,000	20,152,000	— 36.3

[1] Includes 8,000 barrels benzol and 306,000 barrels exported from bond. [2] Includes 54,000 barrels anti-knock compounds. [3] Includes 9,000 barrels exported from bond. [4] Includes 36,000 barrels exported from bond. [5] Exclusive of 17,000 barrels exported from noncontiguous territories but inclusive of 1,058,000 barrels shipped from U. S. to territories and inclusive of 351,000 barrels exported from bond. [6] Not the sum of the above figures, some of which do not indicate barrels.

justly blamed for price increases resulting from conditions beyond its control. But there is no assurance that industry actually would go free of blame if oil prices should materially advance.

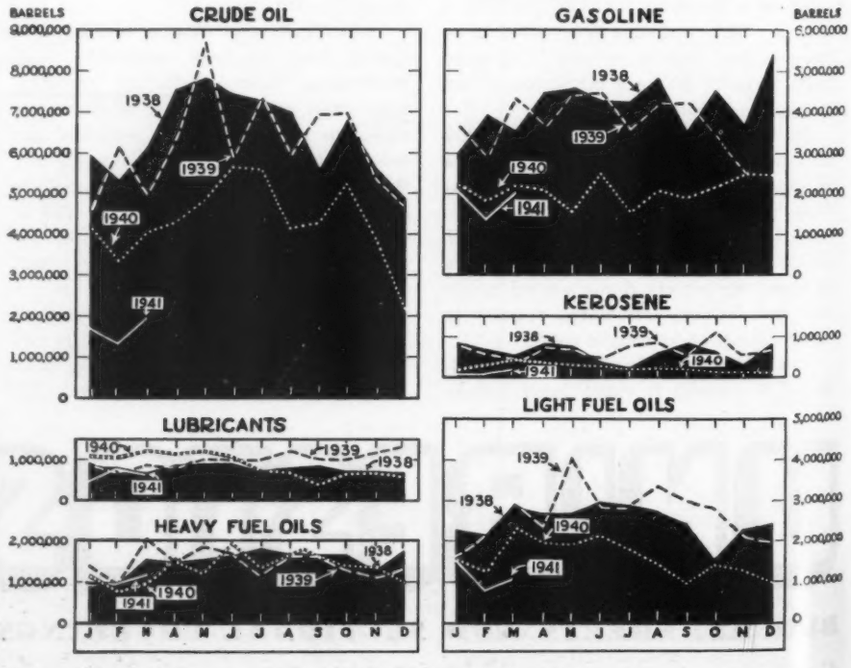
And in the event of public protest, the industry doubtless would be very near to the federal government control that it repeatedly has had to oppose strenuously in recent years.

It is to be expected, consequently, that the industry will be spurred on to extreme effort to work out a successful solution to the transportation problem, not only by its repeatedly demonstrated eagerness to serve its customers well and to do its part in national defense but also by its desire to avoid facing renewed agitation for federal control.

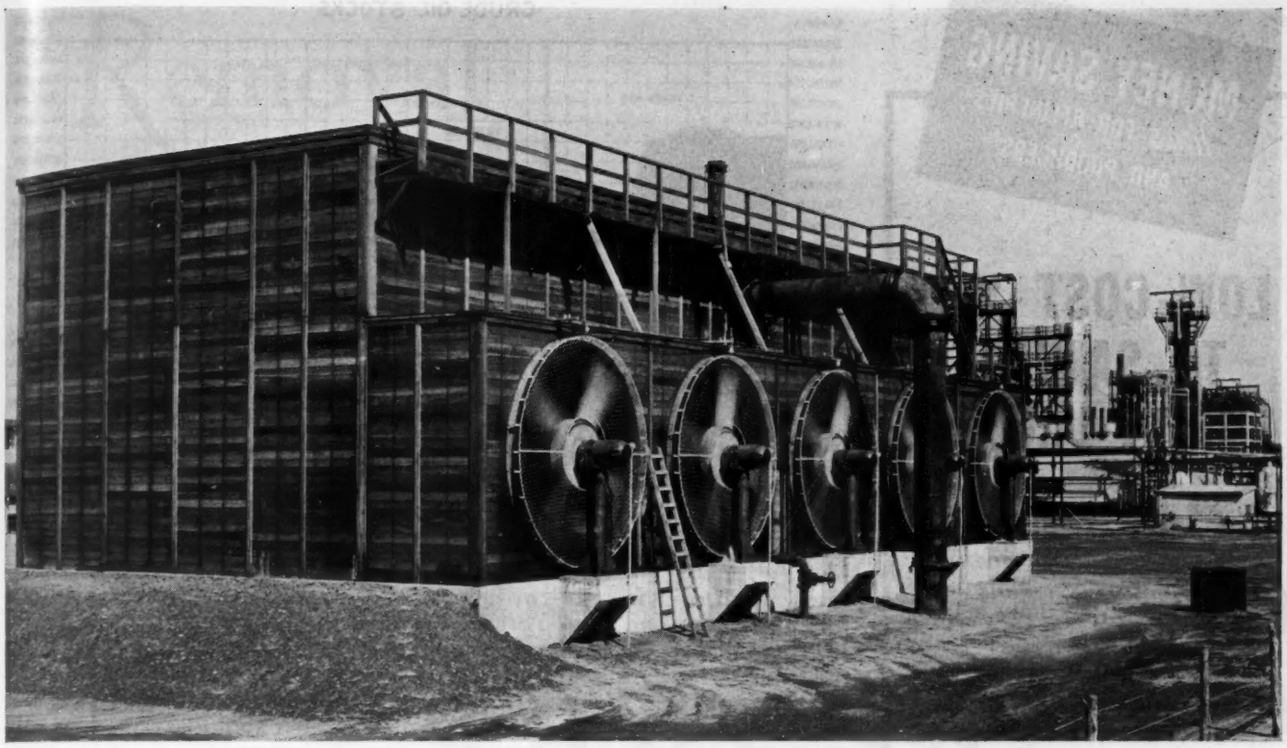
It may not be too much to hope, therefore, that the industry, given any needed government cooperation, will be able to get along satisfactorily without the tankers that it already has given up and henceforth will give up, largely compensating for the surrendered boats by providing new transportation facilities and by increasing the efficiency of existing facilities.

Steps already have been taken which will compensate to limited extent for the diversion of the tankers, including the inauguration of movement of about 37,500 barrels daily of crude from the

U. S. Exports of Crude Petroleum and Refined Products



Source of Data: Bureau of Mines



Lowhead, forced draft cooling tower, of 6000 gallons per minute capacity, in a Texas refinery.

Twenty-foot Pumping Head with Mechanical Draft Cooling Towers

The water pipe in this photograph rises only twenty feet to the cooling tower gravity distribution system; that low pumping head represents one of the most important engineering advances ever effected in cooling water for refinery processes. Drastic reduction in pumping load effects savings in electric consumption throughout the life of the cooling tower.

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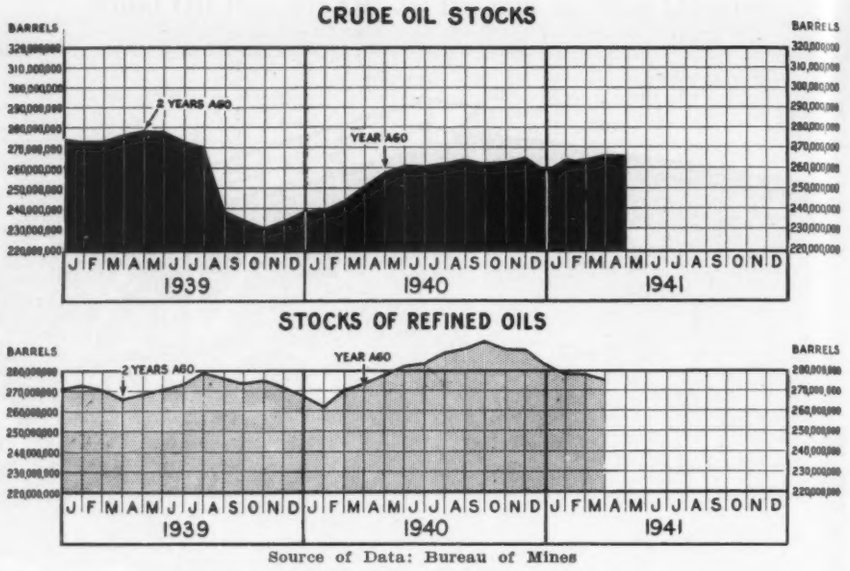
CRUDE OIL STOCKS
BARRELS
2 YEARS AGO
YEAR AGO
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1939
1940
1941
STOCKS OF REFINED OILS
BARRELS
2 YEARS AGO
YEAR AGO
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1939
1940
1941

Source of Data: Bureau of Mines

Mid-Continent through two pipe line systems to the New York and Philadelphia areas, stepping up of movements by barges up the Mississippi and Ohio rivers, increased use of railroad tank car facilities, government action to force railroads of the Southeast to permit oil companies to proceed with construction of two gasoline pipe lines to serve that region, switching of some Atlantic Coast refineries to coal instead of oil as fuel, and substitution of coal for fuel oil in heating buildings of the East. In addition, some expansion of capacity of existing pipe lines across the country, from Southwest to Northeast, is believed possible and likely. Last, and perhaps most important, is the apparently serious proposal to build a 20- to 24-inch pipe line, of estimated capacity of 200,000 to 300,000 barrels daily, from Texas and Louisiana to the New York area, for moving crude oil to refineries in the latter district, with the idea in mind that the line subsequently could be converted economically into a natural gas line.

Moreover, in the tanker field itself, considerable relief from the shortage of boats may be expected. In the first place, the ships left in the hands of the oil companies for the domestic trade doubtless will henceforth be made much more than normally efficient. Increased efficiency will be accomplished by speeding up loading and unloading of boats, with the aid of expanded pumping capacity; by more careful dispatching of crudes and products; perhaps by more heavily loading boats, in view of the emergency; by delaying repairs to tankers longer than normally; and by effecting miscellaneous savings in time. In the second place, construction of tankers currently under way is being rushed as much as possible, and although it has been figured that about 25 tankers would come off the ways in 1941, there are hopes of a substantial speeding up of construction this year and subsequently, in view of the scarcity that has arisen in this vitally necessary form of transportation.

An important prospect which apparently has been overlooked by many, moreover, is that of a slowing down of the expansion of gasoline consumption after this summer in reflection of the scheduled sharp curtailment of production of automobiles. To make available for use in war equipment the materials that would be required in manufacturing passenger automobiles, the production of the latter will be cut at least 40 percent beginning in August, and there have been some hints that output of those cars will be reduced much more sharply than that, if not entirely eliminated. This definitely planned curtailment of automobile production may be expected to be reflected before long in gasoline consumption, as every month brings the scrapping of a large number of worn-out vehicles, which must be replaced by new cars if there is to be no decrease in the number of automobiles in use.

Furthermore, a somewhat similar prospect is offered in connection with consumption of heating oil. Government authorities so far have denied that they contemplate discouraging installation of new oil burners for the sake of conserving heating oil, but they have hinted

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that manufacture of new burners may be restricted, through taxes or withholding of needed materials, in order to release such materials for use in armament. However, the government conceivably may attempt also to alleviate the East Coast oil scarcity by action holding down installation of additional burners. Weather conditions next fall and winter may, of course, minimize or exaggerate any scarcity of the burning oils.

In view of all these developments and possibilities, some petroleum economists and analysts for investment trusts are disposed to be confident that he petroleum industry will continue to function without serious impairment of volumes of business through the tanker situation; that the loss of tonnage will be virtually if not entirely compensated; and that demand for petroleum products will continue to grow and to be met by the industry, despite a possible relatively short retardation through the present transportation difficulties.

Likewise, men of the oil industry, traditionally self-reliant and sanguine, refuse to be greatly disturbed by the tanker situation, regarding it as simply another obstacle which may be somewhat troublesome but which certainly can be overcome, just as other difficulties have been solved in the past. Furthermore, the steps promptly taken already seem to justify that attitude.

It must be conceded, nevertheless, that further steps to alleviate the tanker shortage are urgently needed. In its forecast for June, the Bureau of Mines pointed out that gasoline on hand in the East Coast district on May 1, 1941, aggregated 900,000 barrels less than in 1939, when the level of stocks was relatively low, while inventories on the Texas Gulf Coast were 3,500,000 barrels greater than in 1939.

The tanker problem may become a serious factor, the bureau stated, particularly if combined with larger naval fuel oil requirements and further increases in total domestic demand that will require a more complete use of refinery capacity.

Increased refinery operations in the Indiana-Illinois, Appalachian, and Mid-Continent refinery districts are indicated, according to the agency, and to the extent that larger crude oil requirements are met within those areas, reductions in accumulated storage will be necessary to supplement current production for such states as Oklahoma and Illinois; while ultimately, pipe line movements of crude from more distant sources will be stimulated.

In view of the strong domestic demand for motor fuel and probable further substantial increases in fuel oil requirements, the Bureau of Mines advised that refinery runs should be at a high level and that no abnormal reductions of storage are desirable.

Domestic demand for motor fuel in June is estimated by the bureau at an amount 8 percent greater than the abnormally large actual demand of June, 1940, and 11 percent above the estimated normal for that month. Exports of motor fuel for June of this year are estimated at 1,700,000 barrels, the same as the estimate for May.

Changes From Year Ago in Stocks of Crude and Refined Oils in the United States

(Figures indicate Barrels)

LATEST WEEKLY DATA

(Sources: Crude stock, Bureau of Mines; all other figures American Petroleum Institute.)

STOCKS OF:	May 24, 1940	May 24, 1941	Percen Change
Gasoline	101,557,000	94,811,000	— 6.6
Gas Oil & Distillate	27,413,000	33,102,000	+20.8
Residual Fuel Oil	102,932,000	93,774,000	— 9.0
Crude Oil	*257,647,000	†262,645,000	+ 2.0

LATEST MONTHLY DATA

(Source: Bureau of Mines.)

ITEM	Stocks at End of March		
	1940	1941	Percent Change
SUMMARY—			
Crude Petroleum:			
Refinable in U. S.	251,120,000	266,380,000	+ 6.1
Heavy in California	13,485,000	11,776,000	—12.7
Natural Gasoline	5,393,000	5,331,000	— 1.1
Refined Products	273,845,000	275,560,000	+ 0.6
Total, all Oils	543,843,000	559,047,000	+ 2.8
Days' Supply:			
March basis	138	136	— 1.4
3 Months Basis	139	137	— 1.4
PRODUCTS—			
Gasoline:			
Finished	96,467,000	91,717,000	— 4.9
Unfinished	5,393,000	5,331,000	— 1.2
Total	101,860,000	97,048,000	— 4.7
Aviation Gasoline	4,818,000	6,876,000	+42.7
Kerosene	4,114,000	6,724,000	+63.4
Gas Oil & Distillate Fuels	23,086,000	30,009,000	+30.0
Residual Fuel Oils	89,351,000	82,899,000	— 7.2
Lubricants	8,084,000	8,637,000	+ 6.8
Wax (Thousands of Pounds)	90,373	121,887	+34.9
Coke (short tons)	624,000	375,000	—39.9
Asphalt (short tons)	699,000	831,000	+18.9
Road Oil	924,000	892,000	— 3.5
Miscellaneous	368,000	369,000	+ 0.3
Other Unfinished Oils	36,920,000	40,227,000	+ 9.0

* Stocks May 18, 1940.
† Stocks May 17, 1941.

Wilson Blames Railroads For "Irreparable" Delay

The obstructive position adopted by the railroads toward the crossing of their tracks by petroleum pipe lines has resulted in "irreparable" delay in developing new transportation facilities to offset the withdrawal of tankers from the Atlantic service, the Society of Automotive Engineers, holding their spring meeting at White Sulphur Springs, W. Va., were told June 4 by Dr. Robert E. Wilson, petroleum consultant of the Office of Production Management.

"Both the OPM and the industry has been aware since last summer, long before diversion to British service was contemplated, that there was a tight situation in tankers, and by early last fall orders had been placed for 75 new tankers," Wilson explained. "However, because of the overloading of shipyards with Navy and other business, it has been possible to schedule only 28 for completion during 1941, which was barely enough to meet the prospective growth in demand plus Navy needs. Several weeks ago the Maritime Commission authorized the building of new yards to be devoted solely to the building of tankers, and ordered construction of 72 new tankers in these yards. The first of these will be available about the first of next year.

"The industry and the OPM also have been urging strongly since August, 1940, that rights of way be granted for two large pipe-line projects into the Southeastern States which the industry was ready to build, but these were blocked by railroad opposition and the surprising refusal of the Georgia legislature to enact the needed legislation in spite of urging by the President, the Secretaries of War, Navy and Interior, and by the OPM. It is hoped that this situation will be cleared up very soon by the passage by Congress of the pending Cole bill, which will give federal rights-of-way to interstate carriers certified by the President as being in the interests of national defense. This also will make possible the construction of at least two other major pipe line projects which the industry is ready to build, bringing the total expenditure for new pipe-line projects to relieve the tanker situation, and to be financed by the industry, to well over $100,000,000. However, the delay already suffered is irreparable, and the larger of the projects now needed to cover the tanker shortage will require about 12 months to complete.

"The industry also has indicated its willingness to proceed at once with a cooperative project to build 12 new shipways and construct about 50 large high-speed tankers, again at a cost of over $100,000,000. Again, however, nearly 12 months would be required before deliveries could begin, assuming reasonable priorities."

Wilson told the engineers of the activities of the fact-finding committee of the API, whose report had been laid before the OPM and Secretary Ickes the preceding day, and outlined the steps that have been taken to fill the deficiencies in transportation.

"However," he said, "it is apparent that to fill the gap caused by the diversion of the second lot of 25 tankers will take at least nine months, assuming no more diversions. There also is a shortage of foreign flag tankers to supply the East Coast's customary imports of heavy crudes and fuel oil from Venezuela and other Caribbean points. As a result, it appears that some form of moderate curtailment of East Coast consumption will be necessary this summer and fall."

The Look Box

Army May Select Single Octane Rating

Indications that the United States Army may come to a selection of one octane rating for all its gasoline were made public by General Joseph E. Barzynski when he spoke before the Associated Trucking Industries in Chicago, May 17. One grade of Diesel engine fuel is also an objective. About progress along this line he said:

"Originally the various types of vehicles required gasoline of four different octane numbers and many types of Diesel fuel. We have succeeded in reducing the types of gasoline from four to three. Further progress is being made and I believe it is not impossible eventually to standardize on one single octane number, about 80, and one Diesel fuel.

"The different types of engine oil have been reduced from eight to three; transmission oil from four to two; greases from five to three.

"These changes in motor fuel and lubricants simplify substantially the problem of supply and maintenance and thereby improve the efficiency of the motor fleet. These improvements are the result of cooperative effort on the part of industrial manufacturers and refiners and the various arms and services of the Army."

CONVENTIONS

JUNE	
11–14	**American Society of Mechanical Engineers, Oil and Gas Power Division, Kansas City.**
19–20	**Pennsylvania Grade Crude Oil Association, Bradford, Penna.**
23–27	**American Society for Testing Materials, Palmer, House, Chicago.**
SEPT.	
8–12	**American Chemical, Society, Chalfonte-Haddon Hall, Atlantic City.**
17–19	**National Petroleum Association, Hotel Traymore, Atlantic City.**
29–30	**National Lubricating Grease Institute, Stevens Hotel, Chicago.**
OCT.	
16–18	**American Institute of Mining and Metallurgical Engineers, Petroleum Division, Dallas.**
31	**California Natural Gasoline Association, Los Angeles.**
NOV.	
3– 5	**American Institute of Chemical Engineers, Virginia City, Virginia.**
3– 7	**American Petroleum Institute, St. Francis and Palace Hotels, San Francisco.**

Nolo Contendere Pleas End Madison Anti-Trust Suit

In the final action in the Madison oil industry anti-trust suits, two companies and five individuals entered pleas of nolo contendere before Federal Judge Walter C. Lindley at Madison, Wisconsin, last week, accepting fines totaling $20,000 rather than stand long trials. Charges against two individuals were dismissed.

The suits were filed in the federal court for the western district of Wisconsin five years ago on indictments alleging conspiracy to artificially raise gasoline prices in mid-western states through buying programs, and to control jobber margins through uniform contracts. First trial on the charges extended four months in 1937-38, and resulted in dismissal of some defendants, retrials for others, and conviction of still others.

Defendants entering pleas last week were among those granted retrials, while charges against Harry D. Frueaff, vice president, Cities Service Export Oil Company, Tulsa, and H. E. Brandle, general manager of the company, New York, were dismissed.

Fines of $5,000 each were levied against Standard Oil Company (Indiana) and Cities Service Oil Company. Individuals fined were Edward J. Bullock, vice president, Standard (Indiana), $2,500; Alexander Fraser, president, Shell Oil Company, $2,500; A. G. Maguire, board chairman, Wadhams Oil Company, $1,500; O. J. Tuttle, sales manager, Empire Oil & Refining Company, $2,000, and H. J. Kennedy, vice president, Continental Oil Company, $1,500.

Testing Course at Kilgore College

A 12-week course in fuel and lubricant testing will be given at Kilgore Junior College, Kilgore, Texas. Texas Agricultural & Mechanical College will conduct the classes, which will be at night. The course has been approved by the government. Classes started June 9 and will continue for 12 weeks.

Qualifications for admission are two years of college engineering and training with at least inorganic, qualitative, quantitative chemistry and physics. Information can be had by writing Henry Emmett Gross in care of W. L. Dodson, president of Kilgore Junior College, Kilgore, Texas.

Tide Water Associated Officials Reelected

All officials of Tide Water Associated Oil Company were reelected at the annual meeting of directors in May and U. B. Boucke, controller, was elected a vice president.

Those reelected are: William F. Humphrey, president; C. R. Barton, L. F. Bayer, J. D. Collins, L. C. Decius, B. I. Graves, K. R. Harkinson, George J. Hanks, L. D. Jurs, R. B. Pringle and Edward H. Salrin, vice presidents; U. B. Boucke, controller; William J. Burker, secretary; K. R. Hankinson, treasurer; J. P. Edwards, executive secretary.

Walter L. Abbott, president of Aetna Oil Company, Louisville, Kentucky, died May 18 after an illness of three months.

Washington Oil Round Up

RAPID and involved were the events in petroleum from mid May to mid June. Requisitioning of 50 tankers for service to Britain came in May with the result that the industry faced the problem of providing methods of transporting its oil and gasoline from the Gulf Coast to the Atlantic Seaboard. And these events have come about:

Harold L. Ickes has been named Coordinator of the petroleum industry;

Anti-trust litigation pending against 22 major oil concerns and the American Petroleum Institute has been left to the discretion of the new coordinator;

A bill to facilitate the building of pipe lines from the Gulf Coast to the Atlantic seaboard has passed the House of Representatives;

Recent crude-oil price increases have come under the scrutiny of authorities in Washington;

An increase of 25 percent in refining capacity for 100-octane aviation motor fuel has been recommended by OPM;

Objection to shipments of crude oil and gasoline to Japan have become numerous and vindictive;

By diverting shipments and augmenting pipe line capacity the industry has set out to ship more Mid-Continent oil to the Atlantic Seaboard.

Designation by President Roosevelt of Secretary of the Interior Harold L. Ickes as petroleum coordinator for national defense May 28, set in motion a series of developments which will have profound effect upon the oil industry of the United States.

The appointment of Ickes to approximately the same position of dominance over the oil industry which he held as administrator under the National Industrial Recovery Act was received with mixed sentiments, and there were immediate insinuations that the Administration had taken advantage of the defense emergency to gain the control of the industry which for eight years it had been unable to secure by other means.

There were indications that all further efforts to press the federal control legislation would be dropped, at least for the time being, and that the oil coordinator would depend upon the powers vested in him by the President to deal with any situation which might need corrective measures.

Ralph K. Davies, vice president of Standard Oil Company of California, was named deputy coordinator June 9. Davies is an authority on marketing, having been in charge of Standard Stations, Inc., retail sales wing of the company prior to becoming vice president in 1935.

In his letter notifying Secretary Ickes of his appointment, President Roosevelt pointed out that there are various problems which require immediate action in the interests of national defense, including: "the proper development, production and utilization of those reserves of crude oils and natural gas that are of strategic importance both in quality and location; elimination or reduction of cross hauling and petroleum and its products and the development of transportation facilities and of methods by which more efficient use can be made of existing transportation and storage facilities; balancing refining operations to secure the maximum yields of specific products with full consideration for requirements, the most economical use of the raw materials, and efficiency of production and distribution; and the elimination of the drilling of unnecessary wells in proven fields and of other unnecessary activities and equipment."

Ickes' Responsibility

As petroleum coordinator, the President said, Ickes would have the responsibility:

"To obtain currently from the states and their agencies, from the petroleum and allied industries, from the officers and agencies of your department, and from other appropriate federal departments and agencies information as to (a) the military and civilian needs for petroleum and petroleum products, (b) the factors affecting the continuous, ready availability of petroleum and petroleum products for those needs, and (c) any action proposed which will affect such availability of petroleum and petroleum products.

"To make specific recommendations to any appropriate department, officer, corporation or other agency of the federal government, particularly the Office of Production Management and the Office of Price Administration and Civilian Supply, to the appropriate agency representing any state or any combination of states, and to any appropriate industry or part thereof, as to action which is necessary or desirable, on the basis of your determinations, to insure the maintenance of a ready and adequate supply of petroleum and petroleum products.

In carrying out these responsibilities," the President instructed, "it is expected that you will consult with the several officers and agencies of the federal government, and with the states acting severally or in any joint capacity, to the end that all governmental participation shall consistently further the purposes above outlined. It is also expected that you will consult with the petroleum industry and those industries which affect its functioning, to aid them in shaping their policies and operations in the discovery, development, production, processing, transportation, storage, distribution, marketing, consumption, and import and export of petroleum and petroleum products."

Frank Buttram Approves

The President's action in establishing federal control over the oil industry was hailed by Frank Buttram, president of the Independent Petroleum Association of America, as affording an opportunity for a coordinated defense effort which would be impossible so long as companies attempting to cooperate for defense activities were subject to "harassment by other governmental agencies" for violation of the anti-trust laws.

"I am quite sure that the petroleum industry will welcome and give the most careful consideration to whatever suggestions the new petroleum coordinator may make in order to develop the highest degree of efficiency and team work," Buttram said.

"I am also confident that the various state regulatory bodies will welcome the opportunity to coordinate their activities in order that all military and civilian needs may be promptly and fully supplied."

"Our transportation problem which has been made acute by the diversion of so many tankers from our use to the British service is just one illustration out of many which present an opportunity for the coordination of the best thought and activity of the federal government, state governments and the industry," he said.

Kansas Congressman Critical

Charging that the Administration had used the national defense emergency to gain a control over the oil industry which it had been unable to secure by other means in more than eight years, Representative Frank Carlson (Rep., Kans.) warned on the floor of the House June 2 that far from cooperating with every agency dealing with oil, as provided in the executive order, "rigid rules and regulations will soon be the order of the day."

Carlson asserted that there is no reason why the transportation inadequacy resulting from the transfer of 50 tankers to British service should not be overcome, and expressed displeasure that American tankers are used to haul Venezuelan crude from British account instead of transporting gasoline produced in this country. "In fact," he declared, "Great Britain should insist on this as a reward for our generosity."

He told the House that there is an ample supply of motor fuel in the United States for all demands, domestic and defense and that the purchase by Britain here of the oil she is taking from South America would not have interfered with our conservation program.

Representative Compton I. White (Dem., Idaho) challenged Carlson's statement of the adequacy of our reserves, disclosing that an expert from the Interior Department had testified before the Public Lands Committee that "of all the known resources that have been discovered in the history

The Coordinator for Oil and His Deputy

AS PETROLEUM Coordinator for National Defense Harold L. Ickes, May 31, came into his second intimate contact with the petroleum industry in an extra-curricula activity. The President outlined his duties in a long letter and charged him with the responsibility for "making petroleum and petroleum products available, adequately and continuously, in the proper forms, at the proper places and at reasonable prices to meet military and civilian needs."

He was instructed to call upon other departments of the federal government, departments of the state governments, the Interstate Oil Compact and the industry. What he should or could do after calling upon these divisions of governments and upon the industry was not outlined.

To the industry, however, the appointment was accepted as evidence that another form of control had been set up and that it was the duty of the industry to shape itself to fit the requirements. Immediately there were conferences and immediately there was confusion since press releases gave the impression that Sundays of no pleasure driving were the immediate prospect.

What men of the industry did not say was that they disliked the way Harold L. Ickes conducts himself in petroleum affairs. He was administrator under the Petroleum Code while NRA was a part of the effort to whip the depression. The buying pool, later the basis of the Madison litigation, came into existence then. Many felt that a word from the man who approved the purchasing methods would have softened the prosecution of the Department of Justice.

In 1934 Ickes jolted the industry with a threat of utility control as a means of halting the wasteful practices he recited before the annual meeting of the American Petroleum Institute. More recently the early draft of the Cole bill was accepted as having blossomed in the Department of the Interior.

One of the first moves with the federal government was agreement between the Department of Justice and the coordinator regarding litigation that may come out of joint action to solve petroleum problems, especially improved transportation through joint ownership of new pipe lines. Robert H. Jackson, attorney general, said he approved the move and said efforts were continuing to reach a consent decree on the anti-trust legislation recently filed against major companies and the American Petroleum Institute.

The new coordinator is accepted as having little confidence in the placating practice of sending some oil and gasoline to Japan.

The prospect seemed to be that the move toward coordination might not be to the liking of the petroleum industry but that it would be interesting and forceful. The man on the job has a sharp tongue and is quick to move.

R. K. Davies, vice president of Standard Oil Company of California, drew the selection of deputy coordinator.

Davies has devoted much of his career in the petroleum industry to marketing. A native of Cherrydale, Virginia, in 1912 he went to work for Standard Oil Company of California at Fresno. Later at San Francisco headquarters, he did clerical and sales work, and spent time in special organization activities.

In 1928, he went to London for reorganization work with Anglo-American Oil Company. When he returned in 1929 he was elected vice president of International Bitumen Emulsions Corporation, a subsidiary of the California company. Two years later, he was elected a director of Standard Oil Company of California and executive vice president of Standard Stations, Inc. In 1935, he was elected vice president of the parent company.

He has been president of the Fair Practices Association, a director of the California State Chamber of Commerce, and a consulting professor of marketing at Leland Stanford University.

H. L. ICKES

R. K. DAVIES

of this country we have used up over half of them.

Representative Fred L. Crawford (Rep., Mich.) also questioned the desirability of exporting domestic supplies "under the circumstances which now exist, and under the world-wide undertaking that the President has involved us in."

"I had been under the impression that we were doing the smart thing by conserving our petroleum products to the limit and letting other countries send petroleum products to us if they deem it advisable to do so," he said. "It seems to me we have certainly undertaken a world-wide role, particularly insofar as offshore areas are concerned that can be involved in the Western Hemisphere. Also in connection with the Philippine Islands.

"As to who will control the Dutch East Indies oil I do not know, but suppose the world controlled ships in such a way that oil goes to Japan and Russia and leaves us in a position where we must parallel our action with Britain and protect a great portion of China, a large part of India and that portion of the Malay States which is under British control, together with all of Latin America. Have we sufficient oil reserves to carry out that kind of an obligation? That is the question that is in my mind."

"It seems to me it is one of the things that we might start thinking about," Carlson admitted.

California Price Conference

Moving in on the California situation, Leon Henderson, administrator of the Office of Price Administration and Civilian Supply, called some 30 producing and buying companies to a meeting to be held in San Francisco June 7, for a discussion of recent advances in crude prices with Dr. J. K. Galbraith, director of the price division, and Quinn Shaughnessy, price executive in charge of the fuel section.

The OPACS pointed out that the price of California crudes was increased 5 to 10 cents a barrel on April 24 and that a further increase of 12 cents was announced by Standard Oil Company of California on May 23. Corresponding increases in the price of gasoline, amounting to a total of about 1 cent a gallon, followed.

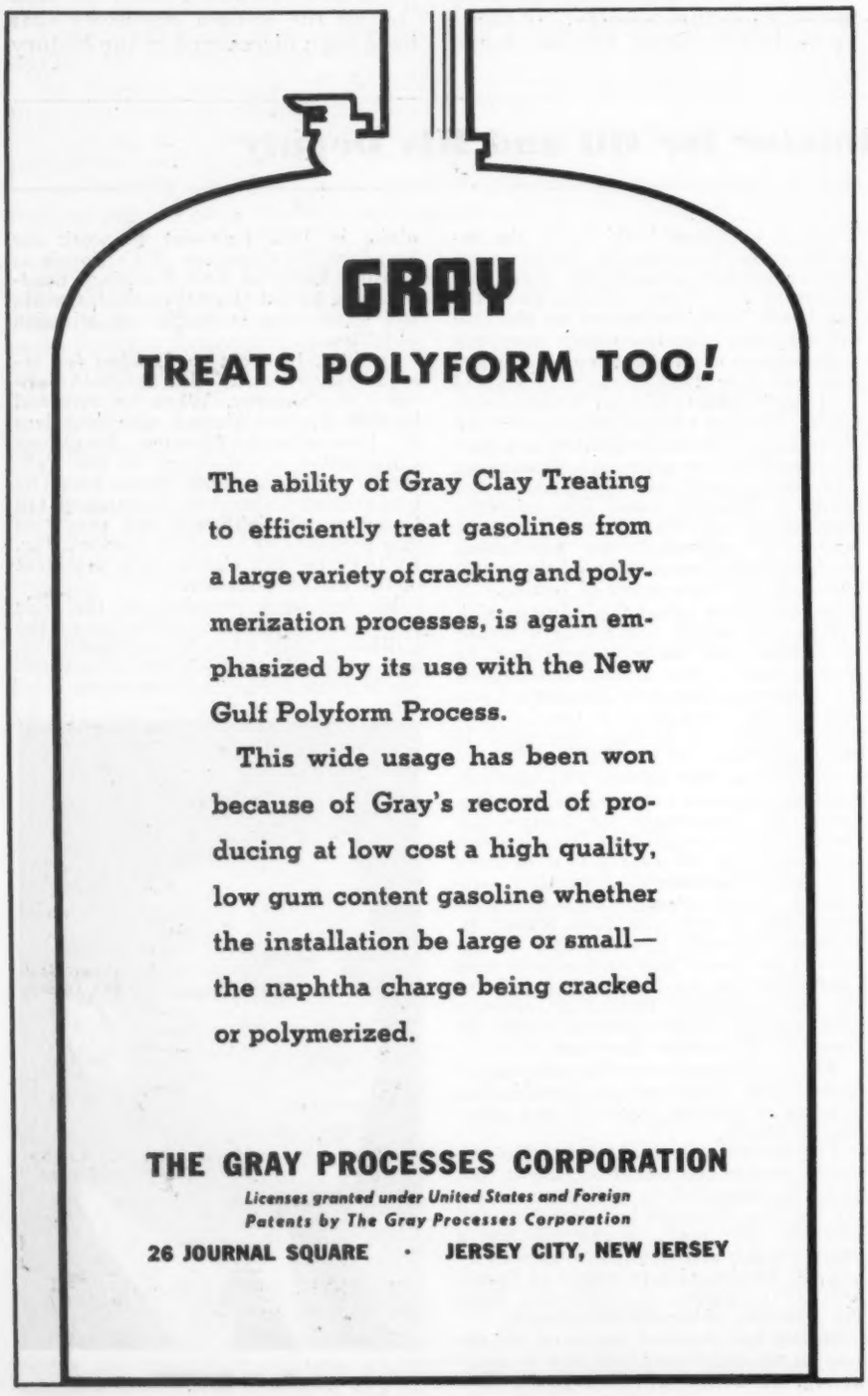
"The last advance in crude oil prices is considered by OPACS to put California crude out of line as compared with prices of crude oil elsewhere in the country," it was stated. "Officials pointed out that crude oil prices are determined by the buyer and consequently are not subject directly to supply and demand factors. Furthermore, it is believed that claimed increases in costs do not justify the present level of prices for California crude oil."

In calling the conference, to which Governor Culbert L. Olson was invited to send a representative, the OPACS served warning that the companies should submit data bearing on costs since "affirmative action" on the situation is contemplated.

Big Suit Up to Ickes

Disposition of the government's anti-trust suit against the major oil companies and the American Petroleum Institute, now pending in the District of Columbia Federal Court, was placed in the hands of Secretary Ickes by Attorney General Robert H. Jackson immediately upon the former's designation as oil administrator.

In a formal statement of the department's position, indicating that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PIPE PUZZLE PICTURE

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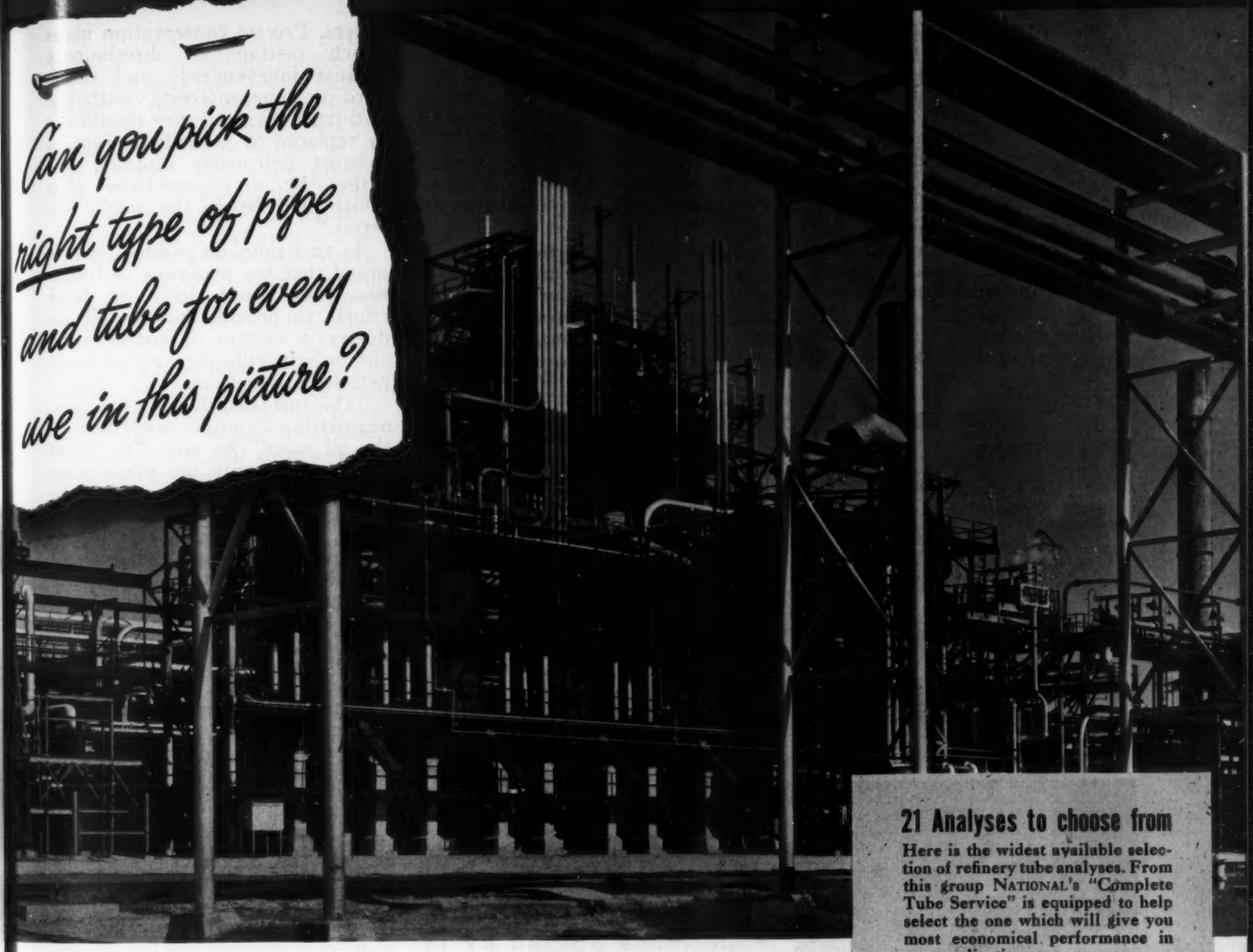

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3 CR., ½ MOLY., 1¾ SIL.
3 CR., 1 MOLY.
5 CR., ½ MOLY.
5 CR., ½ MOLY., 1½ SIL.
5 CR., ½ MOLY., TITANIUM
5 CR., ½ MOLY., COLUMBIUM
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18-8
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it would consent to a shelving of the case if such action was suggested by the Interior Secretary, the Attorney General declared he has "always urged the views embodied in the decision of the President to place the oil industry under the administrative supervision of the Secretary of the Interior."

Jackson called attention to a letter written to Senator Guy M. Gillette (Dem., Iowa) before the filing of the suit last September, in which he said: "In advocating revision of the anti-trust laws over three years ago to make them effective and clear, I repeatedly said that in my opinion the doctrine of compulsory competition embodied in the anti-trust laws is unwisely applied to oil production where the principle of conservation of an exhaustible and irreplaceable national resource should replace the principle of competitive exploitation.

"The companies seem to recognize this for they have tried to limit depletion by devices of their own, but without representation of the public interest or the consumer welfare, or that of smaller producers. Private conservation plans which restrain or discriminate against independents and disregard consumer interests violate the anti-trust laws, but they should not be replaced by a headlong race to exhaust petroleum supplies, but rather by a conservation plan which will be in the public interest."

At that time, he pointed out, he urged that the pendency of litigation should not delay or deter efforts to provide for the oil industry a system of conservation and orderly utilization of our basic petroleum resources.

"The anti-trust division has been negotiating a consent settlement of the oil cases," he said. "To avoid any conflicts with the administrative program which may be established by the Secretary of the Interior, further negotiations in the pending proceedings will be submitted to him, to the end that the national-defense objectives of the new oil control shall be in no way impeded."

Amplifying his statement in a letter to Secretary Ickes, June 3, the Attorney General suggested coordination of the Department of Justice and Oil Administration to the end that anti-trust problems might be dealt with quickly and satisfactorily.

"In fairness to the oil industry," he told the Secretary, "I believe that it should be made clear at the outset that the procedures are not intended to condone any circumvention of existing law but are designed to implement your program and to establish coordination between the administrative control of the oil industry and the enforcement of the anti-trust laws. This procedure is designed to deal both with pending litigation and with future matters that may arise."

The most expeditious way of dealing with the pending suit, he suggested, would be for the department to acquaint the Secretary from time to time with the general course of the negotiations and obtain his views on any major issues which may arise in connection with specific proposals that may be made by the industry prior to final decision by the department. "I assure you that we shall give careful consideration to your views regarding either the economic aspect of these problems or their effect upon national defense," he said.

"As to problems which may arise in the future," the Attorney General wrote, "my department stands ready to implement your activities.

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Any proposals for future civil or criminal proceedings under the anti-trust laws may, before authorization by me, be submitted to you for advice as to whether the proposed proceedings would in any way conflict with your program and, if not, as to whether because of your work the case should be conducted as a preferred proceeding. I will determine authorization and classification after receiving your advice, which I hope you can arrange to furnish expeditiously.

"If, in connection with your work, any questions arise as to the validity of any proposals for group action by the industry, this department will be happy to consider such proposals and to advise you of our views regarding them. Likewise, we stand ready at all times to furnish you such information as is now in our possession in regard to the industry. If at any time you should discover apparent violations of the anti-trust laws which are detrimental to national defense and will so advise this department, we will give such cases priority of investigation and prosecution. In matters not covered by this arrangement, we will establish informal cooperation with your office.

"I am confident that these steps will aid substantially in coordinating our work with your own to the end that the interests of national defense may be served."

More Areas Report Under Connally Act

First formal action of Secretary Ickes as oil administrator was to order the extension of the monthly reporting system under the Connally "hot oil" Act to the Gulf Coast and certain areas in West Texas, involving 441 fields with 37,395 wells flowing as of January 1, last; all of Louisiana's 120 fields with 2300 wells, and to important producing areas of New Mexico, involving 3333 wells.

In these areas, monthly reports will be required from producers, transporters and storers, and refiners to enable the federal government to secure accurate information regarding production and refining, and shipments.

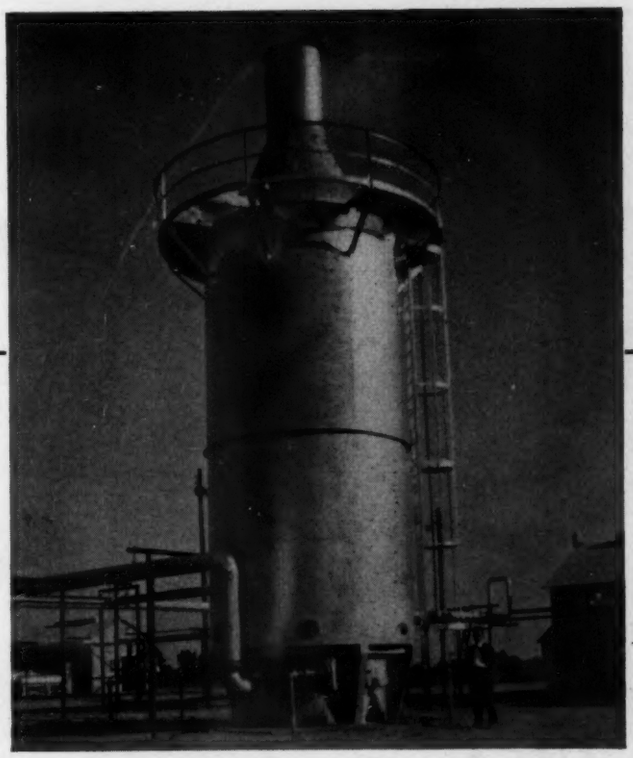
The new fields brought under the act will be controlled from the headquarters of Federal Tender Board No. 1, at Kilgore, Texas, but branch offices probably will be established at strategic points within the several areas.

The area brought under the act in Texas, the department said, constitutes 93 percent of all the flowing wells in Texas, and 47.8 percent of the proven reserves of the country; Louisiana is estimated to have 4.6 percent of the proven national reserves, and the New Mexico area 3.5 percent.

API Report "Highly Confidential"

Meeting with officials of the Office of Production Management and later with Secretary Ickes, the fact-finding committee of the American Petroleum Institute on June 3 submitted a lengthy report on the current Atlantic Coast situation which officials said contained "highly confidential" material and in which specific recommendations were proffered for meeting the oil shortage which is expected will make itself felt in the near future.

Envisioning gasolineless Sundays, restriction of residual fuel oil consumption, reduction of house temperatures in order to save distillate fuel oil, and restrictions on the use of kerosene for heating purposes on the East Coast, the report recommended that a formal, industry committee be set up to work out, with the federal agencies,



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all problems relating to the defense use of petroleum and its products.

Following the conference with Secretary Ickes, W. R. Boyd, Jr., executive vice president of the API, told reporters that the oil administrator was favorably impressed with the committee's work, and that the group will continue to function in order to fill in various parts of the surveys which have been initiated, particularly regarding a proposed pipe-line program, and there were indications that the group will further investigate the possibilities of barge transportation, sending a questionnaire on that subject to companies throughout the industry over the signature of Secretary Ickes.

A number of projects were outlined for consideration by the formal industry committee which was recommended, among them: The exchange of products to avoid needless transportation operations; assistance to government agencies in relation to purchases and deliveries; conservation of supplies and materials used by the petroleum industry; priorities; protection of industry facilities; shipbuilding and construction of other water transportation facilites; and all transportation problems, including pipe line, tanker, barge, tank car and tank trucks.

"The committee cites the above as illustrative of some of the problems that immediately come to mind," it was explained, "but as the dislocation of transportation facilities will carry its effects back to the entire oil producing, refining and distribution branches of the industry, obviously, there will be very many other problems not specifically mentioned which will have to be met and dealt with cooperatively."

Tonnage Lost

In a summary of the report submitted to the OPM and Secretary Ickes, details of which were held strictly confidential, the API committee pointed out that as a result of the diversion of 50 tankers to British service, there is a tanker tonnage shortage against total United States requirements, including imports, of 494,000 deadweight tons average over the third and fourth quarters of this year and the first quarter of next year, reaching a peak in the last quarter of this year of 636,000 deadweight tons.

"This assumes no further requisitioning of American flag tonnage and in addition that the amount of foreign flag tonnage used for imports during the first quarter of this year will continue to be available," it was stipulated. "To the extent that further requisitioning of American flag ships takes place or foreign flag boats now used for imports become unavailable, the above shortages will be correspondingly increased. Against further withdrawal should be considered the possibility of the application either directly or indirectly of seized and interned tankers in Western Hemisphere ports against trans-Atlantic service."

However, the report continued, it is possible that there may be some alleviation of this shortage by increased barge and pipe-line movements, the easing of load limitations on tankers, substitution of Gulf Coast Supplies for the intercoastal movement, and rearrangement of South and Central American supplies which might reduce the shortage to 230,000 deadweight tons.

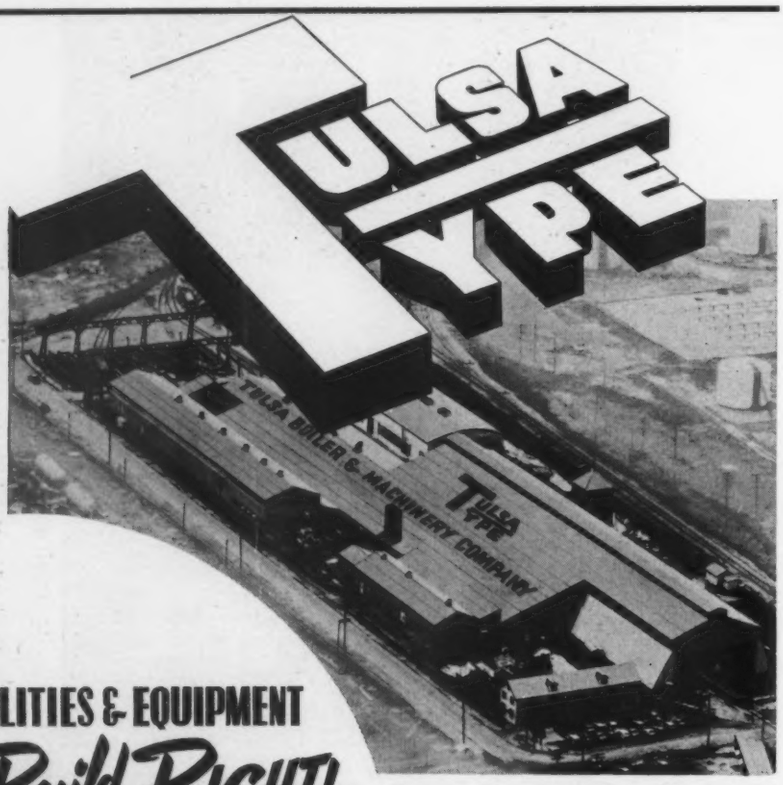
East Coast Needs

During the current year it is expected that, without any restriction, consumption on the East Coast would include 224,000,000 barrels of motor fuel, 161,000,000 barrels of residual fuel oil, 89,000,000 barrels of distillate fuel, 41,000,000 barrels of kerosene and 12,000,000 barrels of lubricating oil, a total of 527,000,000 barrels.

"To arrive at the probable savings in consumption through restrictions, it is necessary to consider each product separately," it was pointed out. "The only effective way to conserve motor fuel would be to restrict pleasure use through some such device as 'gasolineless' Sundays. It if be assumed that the consumption of gasoline might be reduced by as much as 15 percent without undue hardship and if these were applied to the East Coast, the reduced consumption would amount to 34,000,000 barrels.

"Restriction of residual fuel oil consumption could be brought about by converting to coal plants which are in a position to use either coal or oil. It is not possible to determine how much residual fuel oil could be saved immediately by conversion, but it is estimated that perhaps as much as 15 percent of the total demand could be eliminated over a period of several months.

"Distillate fuel oil is used largely for heating purposes. Therefore, any effec-



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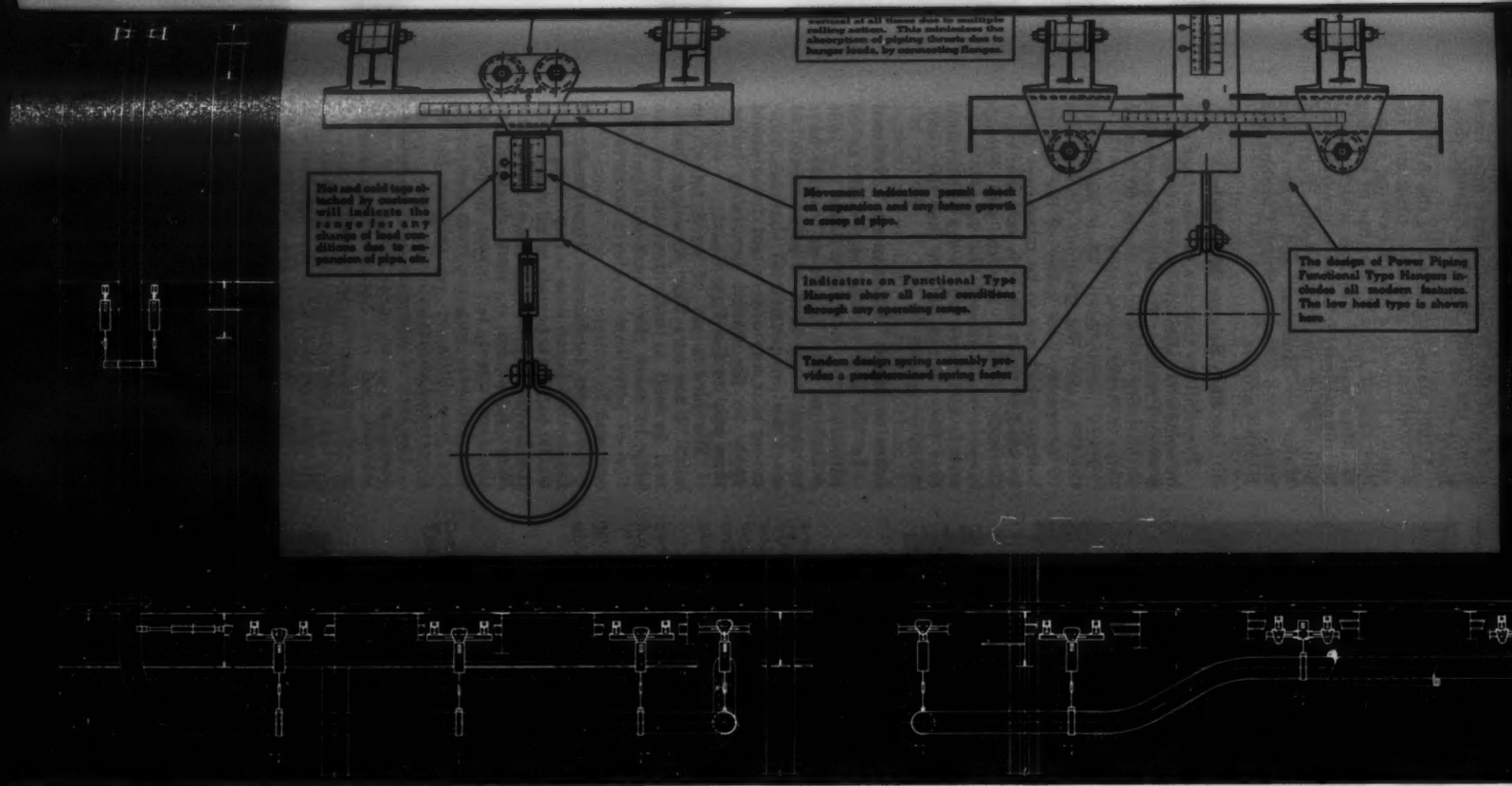
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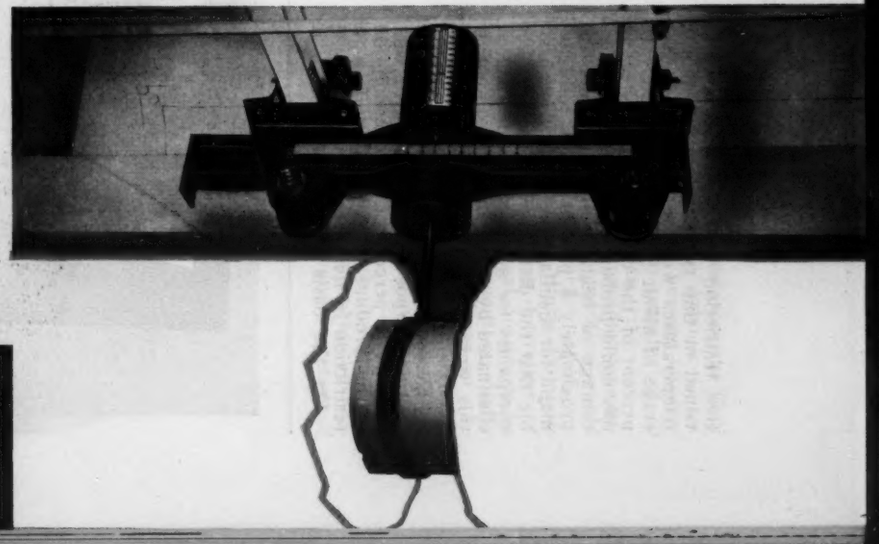

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tive restriction would have to be obtained in this type of usage. If house temperatures were reduced by an average of about 5° F., approximately 10 percent of the consumption of heating oils could probably be saved. This percentage of heating oils represents approximately 8 percent of the total demand for distillate fuel. It is also possible that the distillate fuel used by gas companies for gas enrichment could be eliminated by sacrificing Btu content. If this were done, perhaps an additional 3,000,000 barrels could be saved.

"Kerosene is also used chiefly for heating purposes. It is estimated that perhaps 10 percent of the consumption of this product could be saved through restriction of its use."

On the basis of these estimates, it was declared, approximately 71,000,000 barrels could be cut from the total requirements of the area, equal to 13.5 percent of the total East Coast demand and equivalent to the current carrying capacity of approximately 50 tankers of 10,000 deadweight tons.

Involved in the committee's suggestion for the use of foreign tonnage available here, if further American tankers are turned over to the British, it was pointed out that use of Italian, Danish and German tankers in United States ports would contribute approximately 50,000 deadweight tons, and in addition there are approximately 25,000 tons of idle French tankers in our ports.

Furthermore, Italian, Danish and German tankers in Venezuela account for an additional 50,000 tons, and those in Mexico for 80,000 tons. In addition, the report pointed out, "it should be noted that there are about 100,000 tons of French flag tankers at Martinique."

Balancing all the factors in the situation, the committee came to the conclusion that "barring the withdrawal of additional large amounts of tanker tonnage from the United States and Western Hemisphere service, the situation after the first of next year should be considerably easier, and that the critical period will be during the coming winter.

"If further requisitions or withdrawals of Western Hemisphere tonnage do take place, the only offsetting factors for relief during this period are listed in the report, chief of which are additional tanker construction over that now scheduled and the large products pipe lined from the Gulf to the Atlantic Seaboard."

Other steps suggested by the API for a coordinated pipe-line program included immediate use of existing capacities east of Lima, Ohio; use of existing facilities east of Chicago which might be supplemented by new construction; building of new lines from Portland, Maine, to Montreal, and from Baton Rouge into Georgia, South Carolina and North Carolina.

Ship Seizure May Help

Possibilities that the oil shortage may be somewhat alleviated were voiced June 6 when President Roosevelt signed a bill authorizing seizure of some 80 foreign ships in American waters.

Ickes, immediately upon signing of the bill, asked the Maritime Commission to determine how many of the foreign bottoms which are to be taken over could be used to move oil. It is said that eight German, Italian, Danish and French tankers were among the vessels to be seized, and there was some expectation that they would be put into the Gulf-Atlantic service.

Ickes to Make "Adjustments" National

In his first formal statement as oil administrator, Secretary Ickes on June 4 declared that "all of us" would have to make "some kind of adjustments" to meet the prospective oil shortage, indicating that any orders laid down would apply to the nation generally, rather than only to the East Coast.

"We face a set of hard facts," he said. "I am sure that American industry, as well as individual citizens, can help to meet the situation. Conservation of petroleum products is certainly one way."

Estimates by Interior Department officials that Japan now is importing from 60,000 to 70,000 barrels of oil daily from the United States, sending ships to the West Coast for it, were disclosed by the department, but it was pointed out that Japanese imports from this country bear little or no relation to the threatened shortage in the East.

The lack of adequate supplies will become apparent next month, it was warned, and will become progressively more acute as the year wanes.

Ickes made public statements of representatives of the Oil Burner Institute, pledging assistance in the emergency by bringing about more efficient use of heating equipment in homes, buildings and factories.

Secretary Ickes, on June 5, indicated that he would not hold restrictions up until the shortage became serious, but would impose them almost imme-

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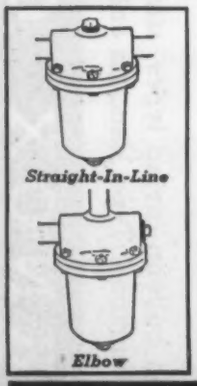

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diately so as to have a margin of stocks for emergency.

He told newspapermen that restrictions will be promulgated within a month or so—"as soon as I can get my feet on the ground, I will do what is necessary," he said.

However, he explained, he will have to study the available data on stocks of the various oil products before making any decision as to what commodities shall be rationed.

The oil administrator gave the impression that the shortage will be more acute than originally figured, saying that it might become so critical as to necessitate an entire suspension of pleasure driving rather than merely "gasless" Sundays.

Already, he had discussed the problem with President Roosevelt and was working on a program to reallocate tanker and other shipping facilities but without hope that it would be adequate to meet the deficiency in supplies.

Rejecting all proposed amendments which might tend to repel the private capital which it is hoped will be employed in the constrution of new pipe lines, the House of Representatives on June 5 passed the Cole bill giving condemnation rights to new lines, government or private, certified by the President as necessary to the national defense.

In only one important respect was the bill amended, the House agreeing to a proposal by Congressman Charles A. Halleck (Rep., Ind.) that any pipe line operated by the government must be turned over to private operation within a year after the end of the emergency.

The bill was brought up in the House by unanimous consent, short-circuiting the Rules Committee, which on June 3 was asked to give the measure right-of-way on the floor but had not acted on the request. It was taken up under an agreement to limit general debate to one hour, but not even that much time was required for discussion, there being no real opposition to the measure.

Under the terms of the legislation, the President may issue a proclamation when he finds that any pipe line in interstate commerce is or may be necessary for national defense. Private companies constructing such lines are to be given the power of eminent domain. In the event private capital cannot be found for the construction of a desired line, the President may order it built by the government.

To insure the completion of lines undertaken by private capital, the bill provides that loans may be made by the government for their completion.

All lines built under the provisions of the bill are to be operated under such terms and conditions as the President may prescribe as necessary for national defense purposes. Under the Halleck amendment, such control would cease and government operation of government-built facilities would end one year after the emergency.

While privately built lines are to be subject to the Interstate Commerce and Natural Gas Act, it is provided that the President may relieve them from conformity with those laws or any act amendatory thereof or supplemental thereto, including the Elkins Act.

In passing the bill, the House rejected proposed amendments which would have prohibited owners of new pipe lines from using them to transport their own products.

Disclosing that he had "heard rumors" that more tankers were to be diverted to the carrying of oil for Britain, Representative William P. Cole, Jr., (Dem., Md.) urged the House Rules Committee June 2 to grant a rule providing for immediate consideration of the government pipe-line bill, and revealed plans for extension of the proposed Baton Rouge-Greensboro pipe line to Philadelphia and an increase in size from 11 to 22 inches, expanding its capacity from 80,000 to 225,000 barrels a day.

Appearing on behalf of the Interstate and Foreign Commerce Committee, which had unanimously approved the measure, Congressman Cole explained that the need for the line from the Gulf producing areas to the Atlantic Coast consuming centers had become imperative as a result of the transfer of 50 tankers from that service.

Were the Georgia situation alone involved, he said, the committee would not have pressed the bill for action.

Cole laid before the Rules Committee a letter from Acting Secretary of the Navy James Forestal, in which he said "the Navy Department is vitally interested in the development of the pipe line facilities contemplated in this bill to insure the expeditions, safe and economical transportation of petroleum products."

He also called the committee's attention to similar endorsements by Secretary of War Stimson and Secretary of

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the Interior Ickes, admitting, however, that the latter's letter had been written prior to his appointment as oil administrator.

Asked by committee members as to the availability of steel for construction of pipe lines, Cole explained he had received assurances from William S. Knudsen and Sidney Hillman, co-directors of the Office of Production Management, that additional transportation facilities would be recognized as essential and that the necessary priorities would be granted for the procurement of pipe.

Private Capital for Lines

Assurances have been given by the oil industry that private capital will be available for the construction of all needed lines, he said, and it is not expected that the government will have to spend a cent on such projects. The cost of the proposed Gulf-Philadelphia line, which actually may go on to New York, was placed at $60,000,000 to $70,000,000.

In contemplation of the construction of the lines by private capital, he pointed out, the committee had rearranged the bill so as to give precedence to such construction and make government construction available only in the event private builders could not be found.

Members of the rules committee expressed opposition to any legislation which would permit the government to operate lines built by it, after the end of the emergency, and suggested an amendment providing that if the government built any lines they would have to be turned over to private operators upon the return of normal conditions.

There was also some question as to whether Secretary Ickes, as oil administrator, did not have the power to provide for the construction of new transportation facilities, and there were suggestions that legislation introduced by Senator Robert R. Reynolds (Dem., N. C.) at the request of the War Department, authorizing the government to take over any private property, involved similar authority.

Construction of a second line from the Gulf to the East also was under contemplation, it developed. Of the two lines, one would be used to move crude oil and the other gasoline. Some confusion exists as to the capacities of the lines, one source placing them at 24 and 20 inches, respectively. Either line could be built in five or six months, it was said.

Investigate Supplies to Axis

Evidence on the movement of United States oil and other war materials to the Axis powers and Russia, and views on the desirability of a Congressional investigation of the situation, were obtained from General R. L. Maxwell, administrator of export control, and officials of the State Department and other agencies June 4 by the House Rules Committee, urged to grant right-of-way for an investigatory resolution sponsored by Representative John M. Coffee (Dem., Wash.).

Decision to call defense officials for questioning was reached by the committee after Congressman Coffee told it that 900,000 barrels of high-test gasoline had been shipped to Japan alone during March, 1941, and that shipments of materials of war, such as machine tools, oil and manufacturing equipment, to Russia "have increased 500 percent recently." Some of these supplies, he declared, were being forwarded to Germany and Italy.

The Congressman declared that the war materials were going to the Axis powers through "third parties" and "dummies." "American and even British companies are selling supplies to the Axis against the spirit of our defense effort, if not against the letter of the law," he said.

Coffee called attention to recent reports of renewal of a contract under which American and British oil companies were delivering millions of barrels of oil to Japan from the Netherlands East Indies, and asserted there also have been reports of oil exports from California to Japan and of oil deliveries by United States and British companies from South America and the West Indies to neutral African ports.

"Trade in war materials is the least of our dealings with Axis powers," he commented.

"American companies are participants with these powers in international patent pools, insurance pools, shipping pools, cartel agreements, gold purchases and financial arrangements whereby money, credit and intelligence are exchanged solely to the advantage of 'double-dealing patriots' in America and their Axis partners.

"An investigation of present conditions now may lead to measures which could shorten the war several years. Indeed, it might result in changing its entire outcome. On the other hand, an apathetic attitude toward the double-dealing situations which now exist may lead to disaster."

Because of the delicacy of the matters involved, General Maxwell and other officials were questioned behind closed doors.

Meanwhile, at the capitol, the threat of gasoline rationing came in for attention, with Representative Raymond Springer declaring gasless Sundays in the United States were so incompatible with continued shipments of oil to Japan that "it should not be countenanced by the people of this country."

Representatives of both the oil industry and oil-producing states are expected to be acquainted with plans of the coordinator at meeting scheduled next week.

Ickes wired Governor Green of Illinois, asking cooperation in bringing about conservation in that state.

"For several years I have been advocating the necessity of petroleum conservation by the oil-producing states," Ickes told Green. "While oil conservation is essential at all times, in the emergency which now faces the country, it is imperative. I urge you to give this problem your immediate personal attention to the end that Illinois enact a law to eliminate as far as practicable the waste of oil and gas and at the same time eliminate the drilling of unnecessary wells."

Commenting on the telegram, Green said:

"Everything possible has been done and will be done to cooperate in any efforts which will further national defense."

The governor recalled it was at his suggestion that the Illinois legislature considered a conservation measure during the current session, and that the measure is still pending.

Aviation Gasoline Expansion

A 25 percent expansion of the capacity for the production of finished 100-octane avaiation gasoline has been recommended by Dr. Robert E. Wilson, petroleum consultant of the Office of Production Management, and the Joint Aeronautical Board of the Army and Navy, it was announced June 4 by the OPM.

The recommendation, which, if followed, would raise the capacity for the production of military and naval aviation fuel to a total of about 50,000 barrels a day within the next 18 months, was made in view of the recent increase in prospective requirements of both the United States and British air forces, it was explained.

"These requiremetns are such that it was deemed necessary to request a 25 percent increase in addition to plants now built and building despite the fact that industry capacity is still substantially greater than present demands and entirely adequate for the next twelve months," the OPM stated.

"While the Army and Navy are not now in a position to place firm orders for the output of the expanded capacity, they have agreed to recommend that any new 100-octane plants, at least up to the total capacity specified, be given the benefit of accelerated amortization for tax purposes."

No expansion in facilities for the production of 91-octane or lower octane gasoline is deemend necessary at this time, it was said.

API Fact Finding Committee Named

At the request of OPM, The American Petroleum Institute in May named a committee to determine what should be done to overcome the transportation problem, which followed diversion of tankers from the Gulf to Atlantic service to shipments from the Western Hemisphere to England.

Those selected by W. R. Boyd, Jr., executive vice president of the institute are: John A. Brown, Socony-Vacuum Oil Company, New York; Robert H. Colley, The Atlantic Refining Company, Philadelphia; H. D. Collier, Standard Oil Company of California, San Francisco; W. S. Farish, Standard Oil Company of New Jersey, New York; W. A. Jones, Cities Service Oil Company, New York; J. Frank Drake, Gulf Oil Corporation, Pittsburgh; J. Howard Pew, Sun Oil Company, Philadelphia; Frank Phillips, Phillips Petroleum Company, Bartlesville; W. S. S. Rodgers, The Texas Company, New York; Reese H. Taylor, Union Oil Company of California, Los Angeles; R. Van der Woude, Shell Union Oil Corporation, New York; E. G. Seubert, Standard Oil Company (Indiana), Chicago; Frank Buttram, Independent Petroleum Association of America; J. C. Hunter, Mid-Continent Oil & Gas Association; N. H. Weber, National Petroleum Association; C. L. Henderson, Western Petroleum Refiners Association; George Reid, Gulf Coast Refiners Association, Houston; Roy Collum, California Oil & Gas Association, Los Angeles; Lawrence Van der Leck, Oil Producers Agency of California, Los Angeles; Parker Melvin, Pennsylvania Grade Crude Oil Association, Oil City; Ray Miller, Natural Gasoline Association of America, and Charles P. McGaha, National Stripper Well Association.

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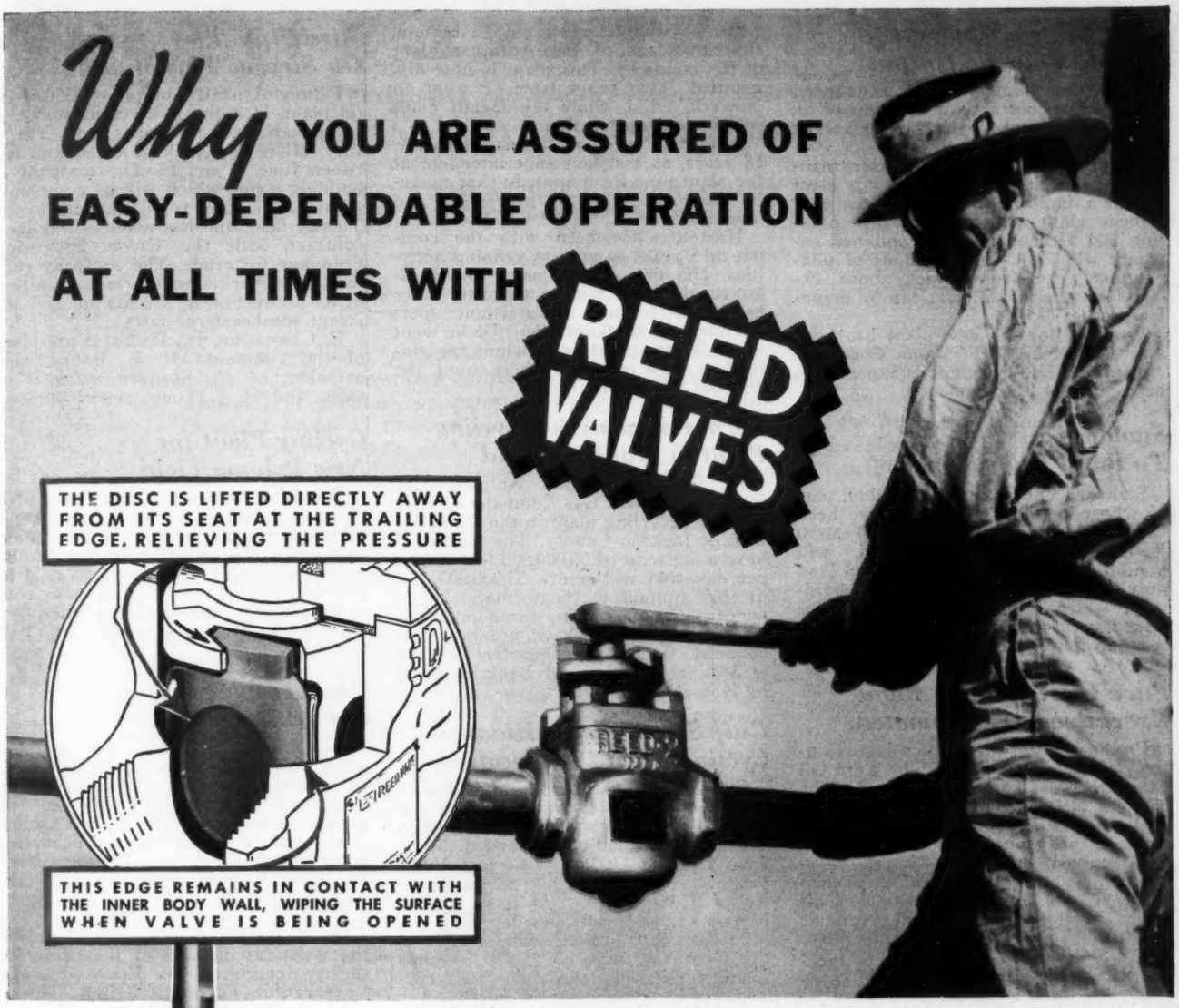
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Shell Awards Contract to Double Toluene Output

Shell Oil Company has announced award of a contract for erection of an additional petroleum toluene plant at its Houston refinery.

According to Dr. R. H. Waser, manager of the Houston refinery, this plant will be a duplicate of the first petroleum toluene plant, which went into operation last December. The combined capacity will be 4,000,000 gallons of toluene per year, from which about 40,000,000 pounds of T.N.T. can be manufactured.

Contract for the new plant has been awarded to the C. F. Braun Company, Alhambra, California, and is expected to be completed by October 1.

Standard of Ohio To Build Laboratory

Standard Oil Company of Ohio, part of whose research activities have been carried out in cooperation with Western Reserve University, Cleveland, will build a new laboratory building on land purchased from the school. The laboratory, which employes 21 workers, is now housed in the power building at the university.

Pure Oil Company Plant Executives Are Promoted

Promotions for three operating executives of refining plants of The Pure Oil Company were announced May 28. The changes include the elevation of Russel L. Vernor from superintendent to manager of the Smith's Bluff plant; Jack S. Allen, who has been assistant superintendent at this plant became superintendent; I. L. Hostetler, assistant superintendent at the Heath plant, Newark, Ohio, became assistant superintendent at the Smith's Bluff plant.

Vernor has been with The Pure Oil Company since 1913. The Smith's Bluff plant was built under his supervision and the capacity has been tripled during his operation of the unit. In 1917 when he was 22 years old he became superintendent of the Ardmore plant of the company. This plant is now dismantled. Two years later he went to Newark, Ohio, while the Heath plant was under construction.

Allen has spent all of his oil career, 18 years, as assistant superintendent at the plant near Beaumont. In that capacity he had charge of processing and operations.

Hostetler has been with the company 15 years in various refining activities. His first work was at the Muskogee plant as resident chemist. Later he was still foreman and assistant superintendent at Muskogee. In 1935 he went to the Heath plant as assistant superintendent and remained there until the transfer to Smith's Bluff.

Form Company for Cycling Plant in Francitas Field

H. B. Zachry, San Antonio, has formed Francitas Gas Company to construct a recycling plant in the Francitas field of Jackson County. The plant will have a capacity of 60,000,000 feet of gas per day, and will return 53,000,000 feet of that amount to the formation. The concern also has plans for a pipe line project, but details have not been announced. General headquarters will be at 308 Second National Bank Building in Houston.

Gulf States Places Hidalgo Cycling Plant in Operation

Gulf States Oil Company has placed into operation a cycling plant in the San Salvador field, Hidalgo County. The plant is handling gas and distillate from sands at 7300 and 7900 feet, being produced by dual wells. It has a capacity of 15,000,000 feet of gas and 350 barrels of condensate per day.

The gas is handled at 1800 pounds in the plant, and boosted to 3700 pounds for injection into the well. Two 600-horsepower engine-compressors power the plant. It is operated under the direction of E. J. Cole, Mercedes, production superintendent.

Mississippi Plant to Go On Stream This Month

Paluxy Asphalt Company's 3500-barrel plant, including a cracking unit and an asphalt plant five miles from Yazoo City, Mississippi, will go on stream between June 10 and 15. The company is building a line which will be completed within a few days from the plant to the Tinsley field, and has made a long-time contract with the Union Producing Company for crude. The company contemplates marketing the major portion of its production in Mississippi and adjacent southeastern states.

E. Constantin, Jr., Dallas, is president of the company; E. F. Bourg, vice president; A. A. Spencer, manager of sales, and H. J. Toup, superintendent.

Cycling Plant for New Paloma Field

Provision for a cycling palnt for pressure maintenance and manufacture of gasoline are a part of the unitization plan under consideration for the Paloma field, California. Operators who hold 84 percent of the structure as now contoured have come into the preliminary agreement. The unit consists of 5900 acres.

Photographic Salon For API Meeting

For the second time a photographic salon will be held in connection with the annual meeting of the American Petroleum Institute. The display of photographs within the petroleum industry will be in San Francisco November 2 to 7. F. Quellmaiz, Jr., room 2040, 50 West Fiftieth Street, New York, will be salon director.

O. E. Kurt has been named head of the technical division of the manufacturing department of Ethyl Gasoline Corporation. Formerly he was in the research laboratory at Detroit. His new duties required his transfer to Baton Rouge, Louisiana.

R. L. VERNOR

J. S. ALLEN

I. L. HOSTETLER

SCIENCE AND TECHNOLOGY

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DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Vapor Pressure Nomograph for Unsaturated Hydrocarbons, D. S. DAVIS, *Ind. & Eng. Chem.* **33** (1941) p. 553.

A vapor pressure nomograph for the unsaturated hydrocarbons is presented. It is based upon the data of Lamb and Roper, and upon the integrated Clausius equation in which the logarithm of the vapor pressure is a linear function of the reciprocal of the absolute temperature. Vapor pressures as read from the nomograph agree with the Lamb and Roper data within 2 percent. A table is given listing the specific constants that enable a larger chart to be constructed if desired.

Relations Between Physical Properties of Paraffin Hydrocarbons, A. W. FRANCIS, *Ind. & Eng. Chem.* **33** (1941) pp. 554-60.

Recent compilations of the physical properties of paraffin hydrocarbons, together with still more recent and reliable determinations of some of them, permit the discovery of nearly quantitative relationships between the properties. These relationships are useful in evaluating the data themselves, and also in predicting missing data. They are of interest to the petroleum industry, especially insofar as they relate to octane numbers, since it is difficult to synthesize or to isolate some of the octanes, nonanes, and decanes in amounts sufficient for accurate determination of the octane numbers. Boiling, melting, and aniline points, density, index of refraction, and octane numbers are given for paraffin hydrocarbons, through the decanes. Equations are derived reproducing directly and probably within experimental uncertainty the densities, indices of refraction, and boiling points of the normal and most of the simpler types of branched-chain paraffins, each as a function of the number of carbon atoms. For each group of isomeric paraffin hydrocarbons: (a) Aniline point is nearly a linear function of density or index of refraction. (b) Octane number is nearly a linear function of 1000 times the density minus twice the boiling point; qualitatively, the higher the density and the lower the boiling point, the higher the octane number. (c) Octane number is nearly a linear function of boiling point plus aniline point. These relationships are used to detect errors in the literature, to suggest possible revisions in values, to estimate the unknown properties except melting point among those listed, and to predict the properties of seven isomers unknown in the literature.

Thermal Data on Organic Compounds. XXI. Some Heat Capacity, Entropy and Free Energy Data for the Four Methylnonanes, G. S. PARKS, T. J. WEST AND G. E. MOORE, *Jour. Am. Chem. Soc.* **63** (1941) pp. 1133-35.

The preparations and some of the physical properties of the four isomeric methylnonanes were described by Calingaert and Soroos. The hydrocarbons were loaned to the authors, who measured the specific heats between 80 and 298° K. The corresponding heats of fusion were also determined. The entropies of the hydrocarbons in the liquid state at 298.16K were calculated from the heat capacity data. The corresponding free energies of the 2-methyl and 5-methylnonane were also calculated. These are lower than the free energy of n-decane by 1490 and 1300 calories respectively. The data are presented in some detail in tabular form.

Diffusion, Thermal Conductivity, and Viscous Flow of Liquids, R. E. POWELL, W. E. ROSEVEARE, AND H. EYRING, *Ind. & Eng. Chem.* **33** (1941) pp. 430-35.

The authors develop a general theory of viscosity and diffusion in terms of the statistical mechanical theory of reaction rate. Quantitative expressions are obtained that express the processes of the viscous flow, diffusion, and thermal conductivity in terms of the measurable thermodynamic properties of liquids. Variations in the theory involved when molecules of different sizes are interdiffusing are treated. Equations for thermal conductivity and for ionic conductance are likewise developed.

Densities and Refractive Indices of Unsaturated Hydrocarbons, M. L. HUGGINS, *Jour. Am. Chem. Soc.* **63** (1941) pp. 916-20.

The author considers the densities and refractive indices of the unsaturated aliphatic hydrocarbons in the liquid state at 20° C. Data from the literature are analyzed. Tables prepared show, first, that the previously used simple additivity relationships for molal volume and molal refraction are not accurate within, or nearly within, the usual differences between experimental measurements, and

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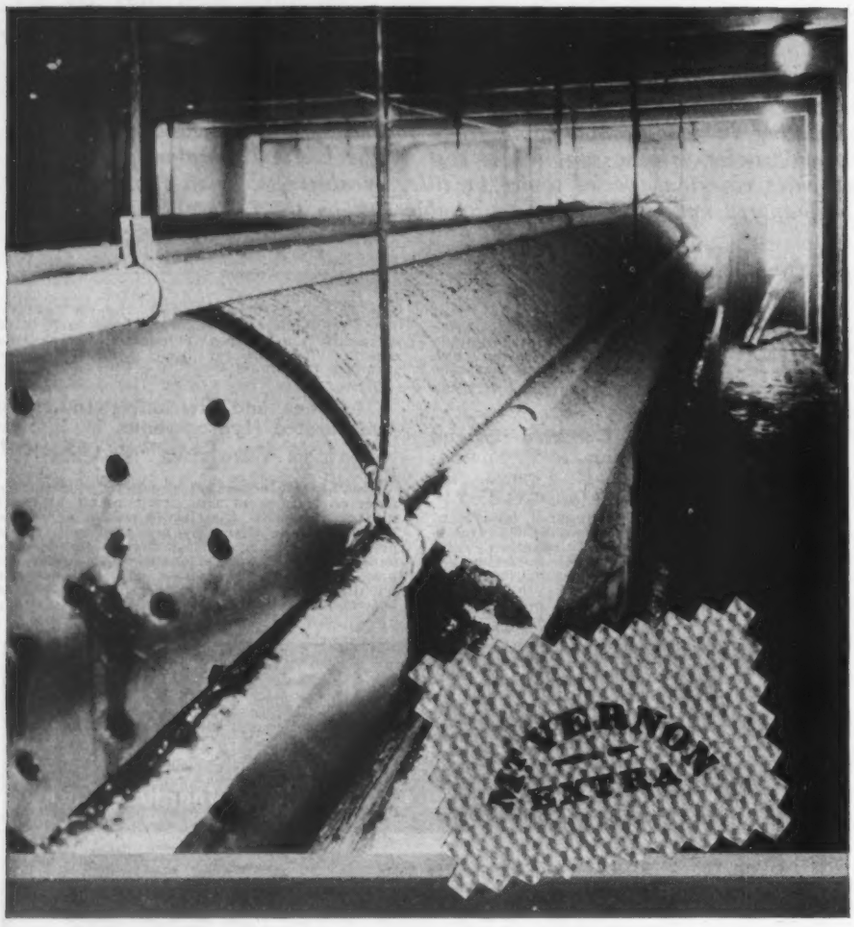

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second that such accuracy can be achieved for most of the compounds by the use of slightly more complicated equations. The constants in the refraction equations deduced agree with the assumption that each bond contributes a characteristic amount to the total molal refraction, depending, not only on the elements joined by the bond, but also on the numbers and kinds of other atoms attached to the two atoms joined by the bond in question. The effect of other atoms is of special importance if two unsaturated linkages are adjacent to (C=C=C) or conjugated with each other as (C=C-C=C). The average agreement between calculated and observed values of both densities and refractive indices is not so good as was the case for the paraffins. This is to be expected on account of the added complexities in the unsaturated compounds.

Chemical Compositions And Reactions

The Polymerization of Olefins. III. The Polymeric Olefins from Methyl isopropylcarbinol, F. C. WHITMORE AND W. A. MOSHER, *Jour. Am. Chem. Soc.* **63** (1941) pp. 1120-23.

The decenes obtained when methylisopropylcarbinol is treated with 75% sulfuric acid have been studied and the results of Drake, Kline and Rose confirmed. Trimethylehylene, 3-methyl-2-pentene, methyl isopropyl ketone, the diisobutylenes, 2,3-4,4-tetramethyl-1-pentene and other nonenes, have been found along with the chief products of the reaction, the two decenes, 3,4,5.5-tetramethyl-2-hexene and 3,5,5-trimethyl-2-heptene. 3,5,5-Trimethyl-3-heptanol has been prepared and dehydrated. Dehydration with copper sulfate and with sulfuric acid give different ratios of the isomers. The relation of this dehydration to the structure of the polymers is discussed.

Chromium Oxide Gel Catalysts for Dehydro-cyclization of n-Heptane, J. TURKEVICH, H. FEHRER, AND H. S. TAYLOR, *Jour. Am. Chem. Soc.* **63** (1941) pp. 1129-31.

Methods of preparation of chromium oxide gel catalysts and their characteristics in the dehydro-cylization of n-heptane are recorded. As alternatives to the preparation of chromium oxide gel by slow precipitation with dilute ammonia from dilute chromium nitrate solutions three methods of preparation have been studied: (a) the formation from a jelly, (b) precipitation as gel from chromic acetate, (c) reduction of chromic acid by alcohol and other organic reducing agents. The activities of the four catalyst types were examined as to dehydrogenation-cyclization activity toward normal heptane and as to the composition of the liquid product in olefins and aromatics. Catalysts obtained by alcohol reduction of chromic acid possess high activities and are readily prepared in bulk. Partial reduction of chromic acid with oxalic acid gives products of high aromatizing activity and that are readily prepared. Reduction of chromic acid by sugar solutions gives only moderately active products. The diminution in activity with time in the aromatization of heptane reduces the activity of the catalyst for the dehydrogenation of cyclohexane.

Thermal Stability, Poisoning, Revivification and Reactivity of Chromium Oxide Gel Catalysts for Dehydrocyclization, D. J. SALLEY, H. FEHRER, AND H. S. TAYLOR, *Jour. Am. Chem. Soc.* **63** (1941) pp. 1131-33.

Data are recorded on the stabilization of chromium oxide gel catalysts to dehydrogenation at temperatures as high as 625° C., together with data on the poisoning and revivification of the catalysts during use. Chromium oxide gel was found to be stable, when properly controlled, up to temperatures as high as 600° C. Dehydrogenation and aromatization of normal heptane is the predominant set of reactions up to 525° C. Conditions for the revivification of spent chromium oxide gel catalyst are given. Water acts as a transient poison for the dehydrogenation activity of the gel catalyst. Transitions from black to green forms of chromium oxide gel catalyst were found to represent states of oxidation of the catalyst and not active and inactive forms for the dehydrogenation and aromatization of liquid paraffins. The glow phenomenon carried out in a non-oxidizing atmosphere, as in hydrogen or nitrogen, does not affect the activity of the chromium oxide gel.

Kinetics of Oxidation of Typical Hydrocarbons, R. A. DAY, JR., AND R. N. PEASE, *Jour. Am. Chem. Soc.* 63 (1941) pp. 912-15.

On account of the parallelism between the tendency of a hydrocarbon to knock when used as a fuel in an internal combustion en-

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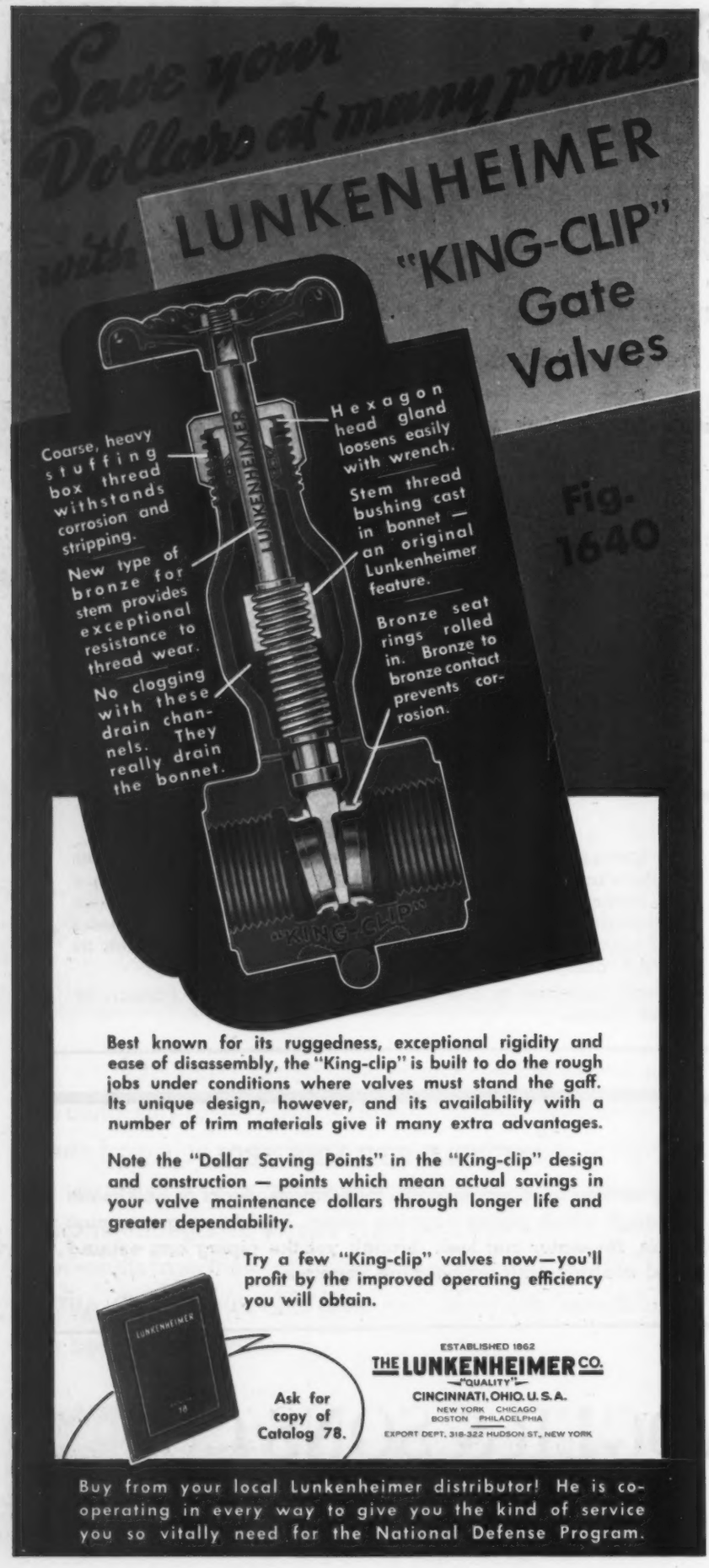
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gine and the ignition and cool flame characteristics a study was made of the controlled combustion of a number of hydrocarbons, including n-heptane, 2,2,3-trimethylbutane, 2,2,4-trimethylpentane (iso-octane), 2,2,3,3-tetramethylbutane (hexamethylethane), benzene, cyclohexane, cyclopropane, and propane. A few runs were also made with propylene, propylene oxide and ethylene oxide. Results of the work show that the order of the hydrocarbons is essentially the same in the measure of rates of slow oxidation and in ignition and cool flame formation. The order also corresponds to the order of critical compression ratios in internal combustion engines. The data relating to hexamethylethane and to cyclopropane are of interest, since no previous work on them has been reported. Hexamethylethane, in spite of its unique structure, is qualitatively the same as it sisomer, iso-octane. Cyclopropane proved to be quite resistant to oxidation. Cool flames were not observed. Ignition temperatures were higher and oxidation rates lower than for either propane or propylene.

Manufacture: Processes And Plant

The Role of Diffusion in Engineering Operations, T. K. SHERWOOD, *Ind. & Eng. Chem.* **33** (1941) pp. 424-29.

The paper is concerned primarily with the presentation of the basic framework of the function of diffusion in the chemical engineering unit operations such as distillation and gas absorption. The basic conceptions are reviewed and their interrelations emphasized. Examples are given of the application of fundamental information, and also a compilation of the types of future research work that seem most desirable. The function of the paper was to outline the background for other contributions to the symposium on diffusion.

Simplified Calculation of Diffusional Processes, A. P. COLBURN, *Ind. & Eng. Chem.* **33** (1941) pp. 459-67.

The purpose of the author's paper was to present a simple method of calculating the number of transfer units, or theoretical plates for the operations of absorption, distillation, and extraction. Although these operations are in widespread use, and notwithstanding the continued development of the theory underlying these processes, there is, in the author's opinion, great need for convenient and sound methods of calculating their best designs. Relatively simple approximate equations are derived and represented graphically for calculating the number of transfer units or theoretical plates for operations such as absorption, distillation, and countercurrent liquid-liquid extraction. These equations and graphs are extended to apply where there is curvature in the operating or equilibrium line, or both. In four examples with marked curvature the approximate equations give answers with deviations from the correct solutions of 2.5 to 6 percent for transfer units and 2 to 9 percent for theoretical plates. The equations derived are summarized in a table and cover absorption, desorption, distillation enriching, distillation stripping with closed steam, distillation stripping with open steam, extraction stripping, and extraction enriching.

Gas Absorption in Bubble-Cap Columns, J. F. WALTER AND T. K. SHERWOOD, *Ind. & Eng. Chem.* **33** (1941) pp. 493-501.

An investigation of absorption extending over a three-year period is reported. Three principal studies were made: (1) the absorption of propylene and isobutylene from an inert gas at moderate pressure in a small bubble-cap column, using as absorption mediums a heavy naphtha, a gas oil, and a solution of gas oil and lubricating oil; (2) the absorption of ammonia and carbon dioxide from air in a single-plate 18-inch column, and (3) the desorption of carbon dioxide from water and from aqueous solutions of glycerol in a single cap column. Data are also presented on the rectification of ethyl alcohol at atmospheric pressure in the 2-inch column, and on the humidification of air at moderate pressures in this same column. Murphree vapor efficiencies of 69 to 92 percent were obtained for the absorption of ammonia, humidification of air, and rectification of alcohol. The corresponding efficiencies were 0.65 to 4.2 for the absorption and desorption of carbon dioxide from water and glycerol solutions, and 4.7 to 24.0 percent for the absorption of olefins in the three oils. The results of the experiment correlate approximately by an empirical equation relating the Murphree vapor efficiency to the gas solubility, the total pressure, the liquid viscosity, the slot width, and the effective liquid depth on the plate. The major variable is gas solubility, and the results indicate that different efficiencies should be used for each component in the design of absorbers for natural gasoline and refinery gases.

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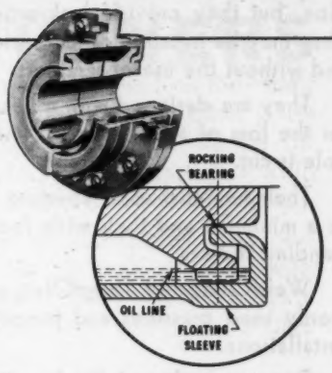

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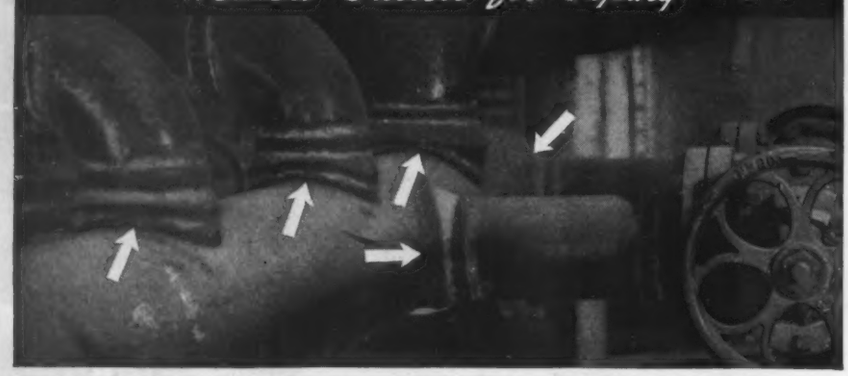

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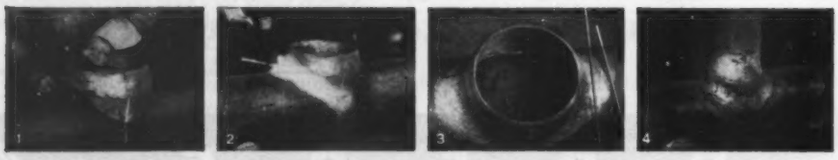

(1)—Select the position of the outlet, rub the fitting over the pipe several times to remove scale, mark center lines and tack the WeldOlet or ThredOlet into position. (2)—The fitting is then welded into place by the electric-arc or oxy-acetylene method. A junction of full pipe strength and a leak-proof outlet is the result. (3)—Where the outlet is 2" or larger, the button should be removed after the welding operation. On small sizes the fitting is used as a templet and the hole is cut in the main pipe first, either with a hole saw, the torch or by drilling. Inspection of the inside of the joint is possible by using WeldOlets and ThredOlets, allowing removal of all scale, welding metal, etc. (4)—The branch line is then welded into position. In the event a ThredOlet is used the branch pipe is threaded and screwed into place.

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Heat and Vapor Transfer in a Wetted-Wall Tower, W. I. BARNET AND K. A. KOBE, *Ind. & Eng. Chem.* **33** (1941) pp. 436-42.

The object of the investigation was to obtain data on the rates of transfer from a gas to a liquid with and without simultaneous occurrence of mass transfer. Because of the scarcity of information on heat transfer between a gas and a liquid without simultaneous mass transfer, this case is of particular interest, especially as it was thought that only the gas film might control the rate. Heat and vapor transfer data were obtained from the operation of a wetted-wall tower with countercurrent flow of liquid and air. Three series of runs were made with different liquids—two with light paraffin-base oils to obtain data on heat transfer from gas to liquid without simultaneous vapor transfer, and the third series with water so that a study might be made of simultaneous heat and vapor transfer. In all cases the gas film was found to control the rate of heat transfer. Correlations for the data were developed and are presented in the article.

Acetone Absorption by Water in a Semi-Commercial Packed Tower, D. F. OTHMER AND E. G. SCHEIBEL, *Trans. Am. Inst. Chem. Engrs.* **37** (1941) pp. 211-36.

The investigation covered the absorption of a soluble component, acetone, from a gas, air, by use of a liquid scrubbing medium, water. Although perhaps not directly applicable in petroleum technology, the principles involved are the same as those concerned with absorption problems in the industry. Acetone in concentrations of 1 to 4 percent by volume in air was removed from the air by scrubbing with water in a packed column made of 10-inch steel pipe 19 feet high. The packing used was 1 inch by 1 inch Raschig rings of stoneware. The following empirical equation was found to hold within the limits of experimental error:

$$K_g a = \frac{1}{\frac{23}{L^{0.95}} + \frac{30}{G^{0.8}}}$$

in which K_g is the overall coefficient as pound mols./hr./sq. ft./atm., a is the area of surface per unit volume as sq. ft./cu. ft., L is the rate of liquid flow as lbs./hr./sq. ft. of column cross section, and G is the rate of gas flow as lbs./hr./sq. ft. of column cross section. The equation is believed to be useful for gas rates up to several feet per second, and liquid rates up to 1000 lbs./hr./sq. ft., and for gas concentrations below 6% by volume of acetone, and for liquid strength up to 7% of acetone. Data for the pressure drop through the column are given. The runs showed a recovery of acetone between 90 and 99% in most instances.

The Effect of Column Holdup on Batch Distillation, A. P. COLBURN AND R. F. STEARNS, *Trans. Am. Inst. Chem. Engrs.* **37** (1941) pp. 291-309.

Although batch distillation is widely used in industry few investigations of a quantitative nature have been made to evaluate the principles underlying the process. The authors present a theoretical analysis of the subject, and also the results of an experimental study using the system toluene-ethylene-dichloride. The laws of continuous distillation are shown not to apply in the cast of batch distillation. Column holdup is found theoretically to have two counteracting effects: one to decrease the sharpness of separation, and the other to increase it. In the work done on the system ethylene, dichloride-toluene, column holdup was found to be beneficial, especially at the lower reflux ratios. The authors state that their work only scratches the surface in evaluating the effect of holdup in batch distillation, and that much further work will be necessary in order to determine the conditions that control whether holdup is an aid or a hindrance, and the degree of its effect.

Hydroforming: A New Refining Process, D. J. SMITH AND L. W. MOORE, *Chem. & Met. Engr.* **48** (1941) pp. 77-9.

The Hydroforming plant of the Pan American Refining Corporation at Texas City is described. It constitutes the most recent addition to the growing family of catalytic processes applied to the petroleum industry. The plant can make high octane motor fuel, high-grade aviation gasoline, or a product containing 80 percent aromatics from a low-octane heavy naphtha. The capacity of the plant is approximately 7500 barrels per day of 40-45 octane heavy naphtha. This is converted in 80% yield to 80 ASTM octane gasoline. The unit is designed to take all of the low-octane heavy naphtha produced from two cracking units having a capacity of 40,000 barrels per stream day each, and in addition some heavy naphtha produced from miscellaneous crude topping operations. The process is distinguished from the hydrogenation process in that hydrogenation involves the addition of hydrogen, whereas hydroforming involves the removal of hydrogen from the hydrocarbons with concurrent ring closure, so that the final product contains a high percentage of

aromatic hydrocarbons and only a small quantity of aliphatic unsaturated hydrocarbons. The product is unusually stable, and is blended directly into finished gasoline. The fresh feed is preheated by heat exchange and sent to a combination naphtha and recycle gas preheater furnace. The hydrogen-rich recycle gas stream from the gas separator is also preheated and sent through a separate coil in the preheater furnace. The two streams issuing from the furnace are then mixed and sent to the catalytic reactors, which operate under pressure. The hot reaction products from the catalytic reactors are partially cooled by heat exchange, and are then cooled to normal temperature and sent through a gas separator. Part of the gas from the separator is used as recycle gas, the balance goes to the refinery fuel system. The liquid from the gas separator is stabilized and then rerun to remove a small amount of heavy polymers. The product from the rerun operation is sent to storage, from which it is blended into finished gasoline. On account of the deposition of a small amount of coke on the catalyst two catalytic reactors are used, one being in service while the other is being regenerated. The article includes a flow diagram of the process, as well as several photographs of the plant.

Perforated Plate Columns for Analytical Batch Distillations, C. F. OLDERSHAW, *Ind. & Eng. Chem., Anal. Ed.* **13** (1941) pp. 265-8.

A perforated plate column is described that has been found to be of special value for the analysis of hydrocarbon mixtures. It combines a low operating holdup per theoretical plate and a negligible static, or nondrainable holdup, with a high capacity. The author states that the column is easy to operate, and that, since it is constructed entirely of glass, it can be used for corrosive liquids. The manner of constructing the column is described in considerable detail. Typical operating data are given for several columns varying in diameter, in size of the holes in the plates, and in plate spacing. With 25 mm. plate spacing, and with holes of about 1 mm. in diameter the plate efficiency varies in the range from 75 to 100 percent. The paraffins are made with other analytical columns, such as those packed with the Stedman packing, and those packed with glass helices. The column described has a somewhat greater H.E.P.T. than the 25 mm. Stedman column, but has a higher capacity. The perforated plate column has a lower average holdup per theoretical plate than the glass helix-packed column.

Nonequilibrium Behavior in Heterogeneous Hydrocarbon Systems, J. B. HATCHER AND B. H. SAGE, *Ind. & Eng. Chem.* **33** (1941) pp. 443-52.

In many of the operations encountered in the production and refining of petroleum, fluids undergo changes in state under such conditions that the probability of attainment of equilibrium is small. For this reason a study of the factors influencing the nonequilibrium behavior of homogeneous and heterogeneous systems was started with the objective of ascertaining the factors pertinent to the formation and growth of bubbles in supersaturated hydrocarbon liquids. The investigation included a study of the behavior of mixtures of propane and n-butane with a water-white hydrocarbon oil at pressures from below atmospheric nearly to the vapor pressure of the component in question. Most of the measurements were made at 100° F. The influence of natural and forced convection upon the transfer of n-butane to and from hydrocarbon liquids was investigated. The usual concept of an effective film thickness was found to be a useful means of comparing experimental results of this nature. Experimental work indicated that turbulence was of nearly controlling importance in determining the degree of supersaturation obtainable in hydrocarbon liquids. Under isothermal conditions natural convection yields a thickness of the effective boundary layer in the liquid phase that increases rapidly as the concentration of the diffusing component in the main body of the solution approaches the concentration of that component at the gas-liquid interface. The present experimental results indicate that the effective boundary layer thickness is relatively constant over a wide range of concentration differences between that in the main body of the phase and that at the gas-liquid interface. Under the conditions of flow normally encountered in circulation conduits, it is unlikely that marked divergences from equilibrium persist for extended periods. However, in laminar flow such as is usually encountered throughout a large part of petroleum reservoirs containing only liquids, rather large degrees of supersaturation are possible.

The Improvement of Mixed Cresols for Inhibitor Purposes: The Use of Mesitol as a Gum Inhibitor, T. KENNEDY, *Jour. Inst. Petr.* **27** (1941) pp. 15-18.

The problem of improving mixed cresols as gum inhibitors consists in increasing the number of ortho- and para-alkyl substituents. A method for the synthesis of mesitol from

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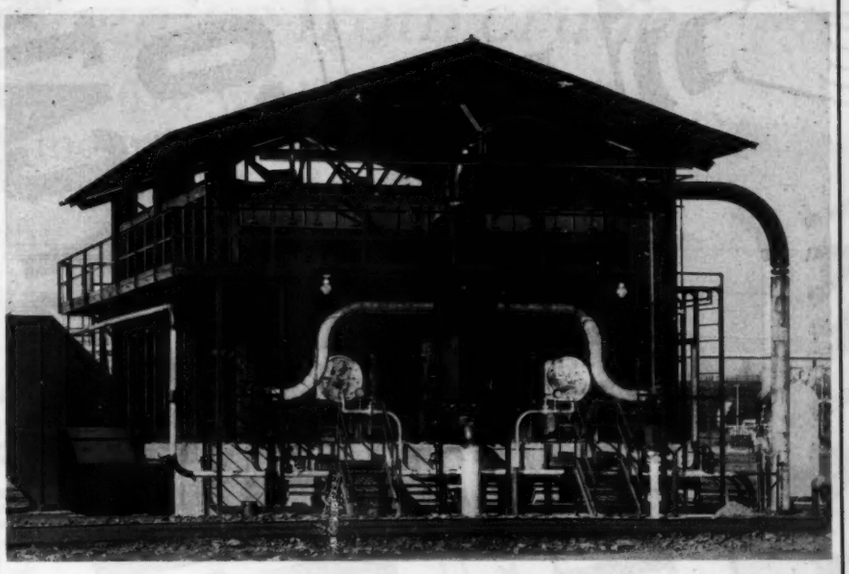

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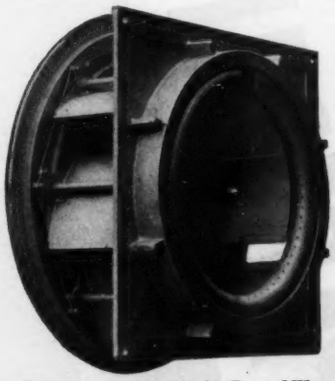

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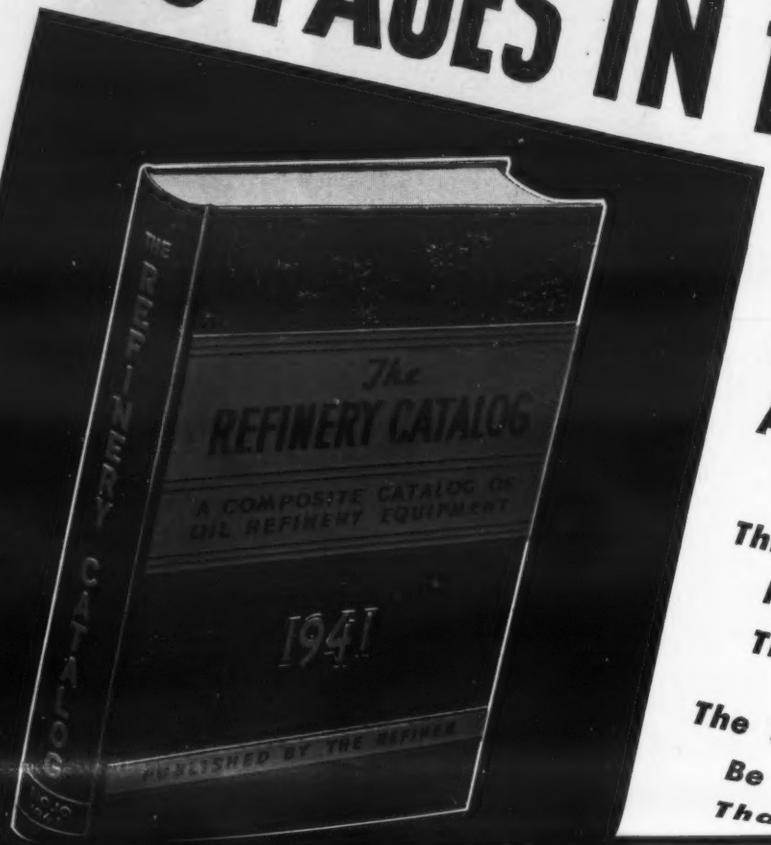

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commercial cresols was investigated and shown to be possible, although experimental variables have not been worked out. Mesitol is 2:4:6-trimethylphenol. It was shown by direct comparison at various concentrations that mesitol has six times the efficiency of o-cresol as a gum inhibitor when the comparison is made on a weight-to-weight basis.

Studies on the Separation of Paraffin Waxes. Part III—The Sweating of Oil-Free Waxes, M. F. SAWYER, T. G. HUNTER, AND A. W. NASH, *Jour. Inst. Petr.* **27** (1941) pp. 1-14.

Sweating was conducted at various regulated rates in an electrically heated sweater of special construction. The apparatus is described in detail. From the work done it was concluded that the melting point-equilibrium temperature diagram previously obtained by the same authors in 14-stage equilibrium experiments is closely similar to that obtained at a low rate of sweating, e.g., 3 percent per hour. The experimental sweater, when operated at low rates, gave a nearer approach to the ideal infinite-stage process than did the multi-stage equilibrium procedure. It is therefore suggested that the diagram obtained at rates of sweating of 3 percent an hour or less is an experimental sweater, such as the one described in the paper, be used as a basis for computing sweating efficiency. The rate of melting is a most important variable. The efficiency of the process decreases with increase in the rate of melting. For example, the yield of a 130° F. melting point wax, when the sweating was conducted at the rate of 3 percent an hour, was 47 percent, whereas, when the sweating was conducted at the rate of 20 percent per hour the yield was 30.8 percent. Preparation of the sample by shock cooling to room temperature results in a wax mass that is more difficult to sweat during the early stages of the process. Cooling the sample to a temperature slightly below the complete solidification point instead of to room temperature, before commencing sweating, results in the formation of a mass that is easier to handle in the early stages of the run. Since the yields of the products are only slightly lower than those obtained when the mass is slowly cooled to room temperature it is concluded that the more extensive cooling from the complete solidification point to room temperature is uneconomical. Local overheating is extremely important; even to the extent of 2 to 3° F. it has an adverse effect on the yield of wax of any given melting point.

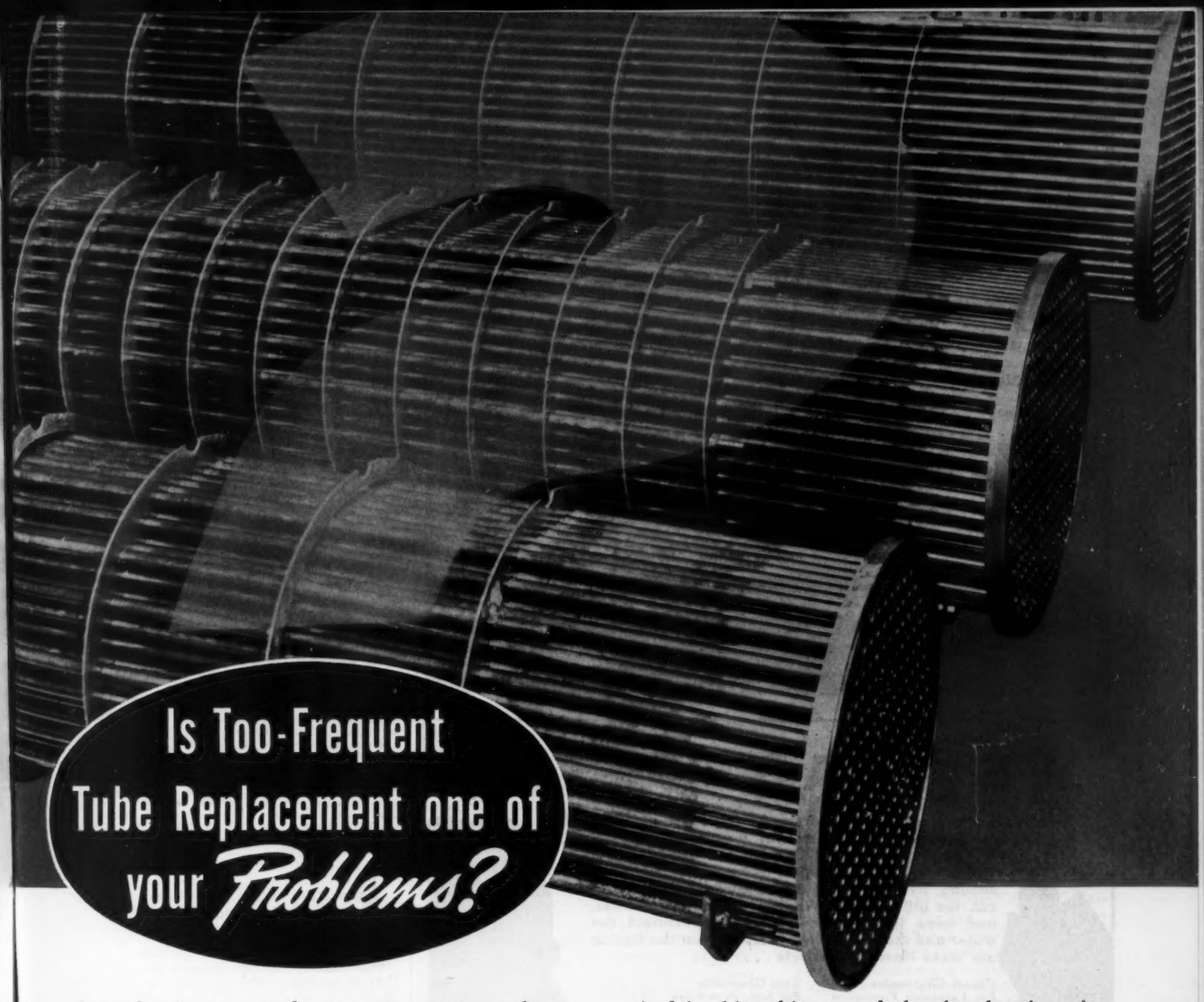
The Effect of Alkyl Substitution on the Efficiency of Phenols as Inhibitors of Gum Formation in Petroleum Products, T. KENNEDY, *Jour. Inst. Petr.* **27** (1941) pp. 19-30.

The effect of alkyl substitution on the efficiency of phenols as inhibitors of gum formation in cracked spirits has been more thoroughly investigated in the case of the six xylenols, and observations have been made on the higher methyl substituted phenols. Substitution by higher-alkyl groups has no apparent advantage over methyl substitution in the para position, although a slight advantage was observed in the ortho position. The efficiencies of 18 phenols on a molecular basis, and as compared to the cresols, are recorded for the inhibition of gum in Iranian cracked spirits. In general, the effect of ortho and para substitution has been found to be about the same. The addition of a third methyl group to a molecule already containing two, confers a great increase in efficiency.

Products: Properties And Utilization

Aromatic Coefficient of Paint Thinners, R. J. DEGRAY AND A. E. ESSER, JR., *Ind. & Eng. Chem.* **33** (1941) pp. 525-31.

A new test for the evaluation of paint thinners is described. This is termed the "aromatic-coefficient" (A.C.). This test compares the amount of xylene needed to reduce a given resin to a given body with the amount of thinner necessary for the same reduction. Since it is based on commercial resins, a widely used standard, and the viscosity scale used in paints and varnishes, the A.C. is of practical application. Resins may be characterized by two constants. With these and the A.C. of the thinner for the resin, the amount of thinner needed to reduce a given resin to any desired body can be calculated. From the minimum A.C. of the resin, the stability of the reduced resin can also be predicted. The A.C. of the thinner is independent of the body at which it is determined from body T to body A. The A.C. of a mixture of thinners is exactly proportional to the composition of the mixture and the A.C. of each component. The A.C. depends upon the resin to be thinned, the



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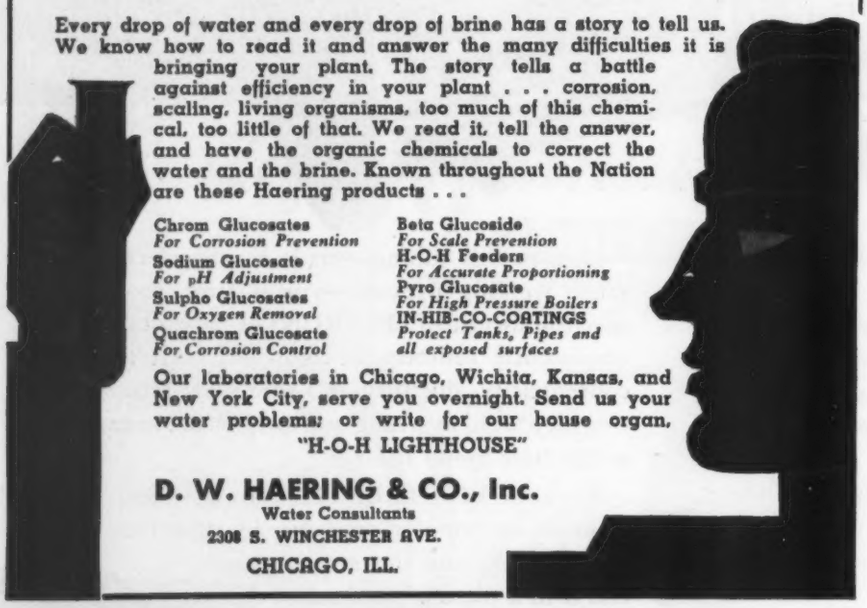

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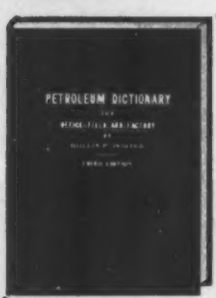

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chemical composition of the thinner, and the viscosity of the thinner. The A.C. of thinners of the same type are straight-line functions of their viscosities. It was found that mixtures of resins must be considered as new resins and studied as such. The reduction of viscosity of a resin by a thinner is a combination of physical dilution and chemical dispersion.

Oxidation of Lubricating Oils, M. R. FENSKE, C. E. STEVENSON, N. D. LAWSON, G. HERBOLSHEMIER, AND E. F. KOCH, *Ind. & Eng. Chem.* **33** (1941) pp. 516-24.

An investigation of the oxygen absorption characteristics and the nature of the products obtained from oils oxidizing under controlled conditions has permitted the evaluation of a number of factors involved in lubricating oil deterioration. Study of selected fractions of a distillate stock has shown considerable variations in reactivity toward oxygen. The rate of oxygen absorption approximately doubles for each 10° C. temperature increase over the interval 140° to 180° C. provided it is not limited by physical factors. The presence or absence of water vapor in the oxidizing atmosphere has little effect on the oxidation of one type of oil. The oxidation of certain oils can be reduced greatly by adding natural or synthetic inhibitors. Clay treatment may either reduce or improve the stability of an oil, depending upon its nature. Iron, copper and lead are strong catalysts for oil oxidation when present either in metallic form or as naphthenate salts. Certain types of oils have a natural ability to counteract the catalytic effect of dissolved iron salts. The use of a phosphite additive controls or eliminates catalysis by certain iron, copper or lead salts, but such additions are frequently accompanied by other changes in the oils so that the over-all effects is more complex than simply a reduced degree of oxidation. Addition agents are capable of making marked changes in the degree of oxidation occurring in oils. They may also influence the direction and character of other accompanying reactions, such as polymerization, condensation, decarboxylation, dehydration, etc., with the result that many of the oxidation products may now be affected independently of the over-all degree of oxidation. In general, addition agents must be studied thoroughly and in detail in order to understand all the changes that are induced by their presence.

Estimation of Unsaturated Hydrocarbons by Bromine Addition, S. J. GREEN, *Jour. Inst. Petr.* **27** (1941) pp. 66-71.

The author briefly reviews the methods that have been used for the determination of unsaturated hydrocarbons by bromine addition. An attempt was made to modify the Francis method by adding a volume of bromide-bromate reagent certain to be in sufficient excess of the theoretical requirements. This modification of the Francis method was compared with the methods of Lewis and Bradstreet. It was found in general that the use of excess bromide-bromate above the theoretical had little influence on the results. The Lewis and Bradstreet method in general appeared to be more accurate. An inhibition effect that might be a potential source of error was observed in brominating heptene, nonene and a benzole fraction by the Francis method. This was not observed when using the Lewis and Bradstreet titration technique. For the estimation of the actual percentage of unsaturateds the bromine absorption method is believed by the author to be unreliable unless the molecular weight and type of the olefines present can be determined or estimated with accuracy.

Microanalysis of Gaseous Hydrocarbons, L. MARION AND A. E. LEDINGHAM, *Ind. & Eng. Chem., Anal. Ed.* 13 (1941) pp. 269-70.

In the study of gaseous reactions the gaseous products are often obtained in such small quantities that ordinary methods of gas analysis do not readily apply. A procedure has been developed applying Pregl's microanalytical method for the determination of carbon and hydrogen to the analysis of gaseous hydrocarbons. About 2 cc. of gas are introduced into the combustion train by means of a buret inserted in the Pregl train. The percentages of carbon and hydrogen are determined. The volume of the sample is also known. It thus becomes possible to determine the molecular weight of the hydrocarbons. The apparatus is described in detail, as well as the procedure for its use. Tables of typical data are included that indicate that the method is accurate.

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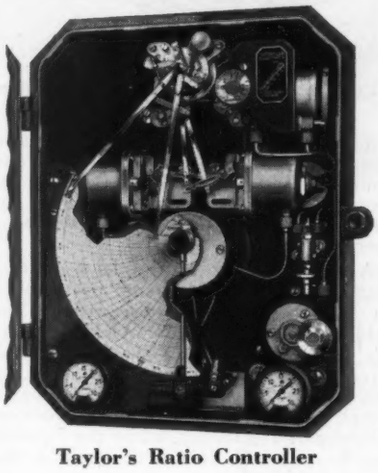

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troller, the ratio is changed by a screwdriver adjustment directly on a calibrated dial throughout the range of 0:1 to 3:1, direct or inverse. It is unnecessary to disturb the processing or remove the chart plate while making ratio adjustments.

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The eyeshield is designed to deflect small flying particles and to afford full unobstructed vision. It is removable and replaceable, and has a rubber-reinforced edge.

In the Dustfoe-Eyeshield combination, the respirator is compact to afford unobstructed vision in every direction. It features United States Bureau of Mines-approved protection against harmful dusts, low breathing resistance, easy maintenance, soft sponge-rubber face cushion, foolproof exhalation valve and protective filter cover. The filter is replaceable. Metal parts are aluminum.

In the Comfo-Eyeshield assembly, the wearer has the protection provided by the Comfo respirator, equipped with twin filters of large area for low breathing resistance. Replaceable filters are protected by metal covers, and the flexible rubber facepiece provides a comfortable fit on any face. All filters, either for dust, fumes or mist, are approved by the United States Bureau of Mines.

Socket and Tool Set

BONNEY FORGE & TOOL WORKS

A light weight socket and tool set, Model TD6, has been added to the line of Bonney Forge & Tool Works, Allentown, Pennsylvania. Sockets and attachments included are all in ⅜-inch square drive, made of chrome-vanadium steel and heavily chrome plated to provide a rust-proof finish.

Containing 40 pieces, it includes 10 sockets with double hexagon openings from 5/16- to 7/8-inch; 4 sockets with 5/8-, 11/16-, 13/16-, and 7/8-inch double hexagon openings; universal joint, 3-, 6-, 12- and 17-inch extensions; 17½-inch speeder; drak link socket; 8½-inch hinge handle; 6-inch cross handle, 7-inch reversible ratchet; 8-inch sliding T; 4 combination box and open end wrenches with 7/16-, 1/2- 9/16- and 5/8-inch openings; Channellock adjustable pump plier with ½- to 1⅞-inch capacity; 4 assorted punches and chisels; pocket size screw driver with neon tube; four wood handle screw drivers of various sizes, and ¾ pound ball pein hammer.

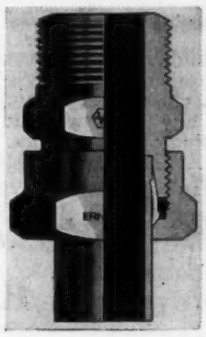
All pieces are packed in a metal box measuring 19 x 5 x 4¼ inches. The box has removable tote tray, carrying handle, end catches and padlock hasp.

The entire set weighs 20½ pounds.

Fitting

THE WEATHERHEAD COMPANY

A fitting designed to provide a safety factor when used with tubing, designated Ermeto safety fitting, has been announced by The Weatherhead Company, Cleveland. It is being made available as nipples, connectors, unions, elbows, tees and sleeves for tube diameters of from ⅛- to 1½-inch.



In application, a cutting edge of a hardened ring shears a groove into the outer surface of the tube, resulting in a joint that is designed to be leak-proof and of a nature that it cannot be pulled apart. No flaring, threading, soldering or welding is necessary, and connections made with the fittings may be taken apart and remade without adversely affecting the tightness of the joint.

Proportioning Pump

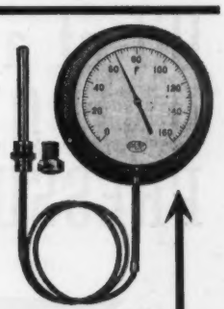
TRANSMISSION ENGINEERING COMPANY

Manufacture of LAB proportioning pumps under a license agreement with Shell Development Company, has been announced by Transmission Engineering Company, 259 Second Street, San Francisco. The former company has used the pumps for a number of years, and holds patents on the design.

The unit features a horizontal pumping end removed from all other working parts, and may be obtained in any re-

MERCURY DIAL THERMOMETERS

1—VERY SENSITIVE
2—EXTREMELY ACCURATE
3—STURDY BUILT
4—EASY TO READ
5—ALL RANGES



Palmer Dial Thermometer Installations have proven to be very satisfactory because of their accuracy and sturdy construction. Stainless-steel flexible tubing connection and bulb are standard without extra charge. Furnished with plain bulb, union connection, separable-socket and flange connection. Ranges: —40 +1000° F. (or 550° C.). Built by craftsmen who know how to make good thermometers. (Write for Bulletin No. 1500.)

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THERMOMETERS: Recording, Industrial, Laboratory and Dial
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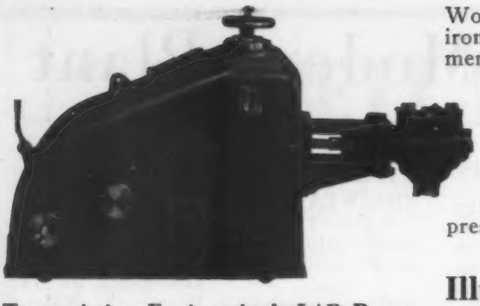

Transmission Engineering's LAB Pump

quired alloy. Any number of units can be connected in parallel to a single driving motor and a clutch mechanism permits release of any unit without otherwise interrupting the service. Working parts are enclosed in a cast-iron sealed housing with a built-in submerged lubricating system having an external oil level indicator.

Length of stroke is adjusted by turning a hand wheel, with an indicating mechanism showing relative capacity. Sizes have been developed to cover a range of capacities to 360 gallons per hour, and pressures to 300 pounds.

Illuminated Magnifier

E. W. PIKE & COMPANY

An illuminated magnifier, powered by dry cell or from current from an AC or DC outlet, designated Flash-O-Lens, has been announced by E. W. Pike & Company, Elizabeth, New Jersey.

Pike & Company's Illuminated Magnifier

The unit employs a double lens system, with lenses precision ground and polished. It may be taken apart for cleaning, and when reassembled the lenses are automatically refocused by a spacer ring.

A side opening in the lens housing permits use of instruments or a pencil on the object under observation. The field of vision is illuminated by an electric bulb so placed in the handle that direct light does not reach the eye. In two styles, the 5-power magnifier has a 2-inch field of vision with a working distance of 1⅛ inches, while the 7-power unit has a 1-inch field with working distance of ¾-inch.

A Bausch & Lomb wide-field, low-power microscope may be adapted to the Flash-O-Lens to provide observation of work carried on several inches from the objective lens. It supplies magnification of 20 times. A portable microscope may also be used to provide magnification of 40 times.

Test Pump

AMERICAN-LaFRANCE-FOAMITE CORPORATION

A test pump designed to determine maximum safe life of fire extinguishers, designated Testal pump, has been announced by American-LaFrance-Foamite Corporation, Elmira, New York.

It tests hydrostatically the shell and hose for strength through the hose and

American-LaFrance-Foamite Test Pump

Improve Your Pump Performance

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OIL PRESSURE UNIT

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MEETING the need for supplying lubricating oil at desired uniform pressure to lantern glands of stuffing boxes. It has a dependable new type pressure regulator adjustable from zero to 1000 lbs. Complete with cooling coil and filter. Electric motor or turbine driven. Standard sizes to handle 1 to 10 stuffing boxes.

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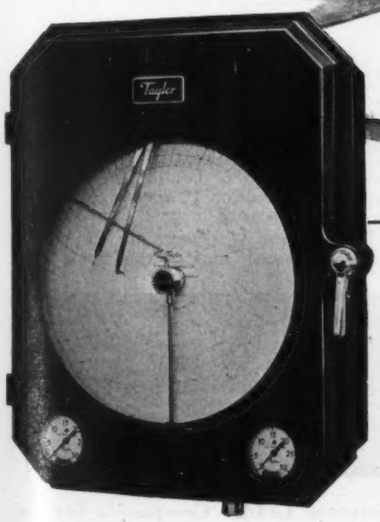
NOT 1 BUT 5 . . . THAT'S THE STORY! NOT 1 BUT 5!



The New TAYLOR FULSCOPE CONTROLLER *handles not 1 but 5 Control Jobs!*

YOU can speed up *quality* production by installing the new Taylor Fulscope Controller. It automatically, absolutely, accurately controls processing operations with the utmost precision. It's the faster way to do your best work,"as per orders."

You can economize by installing the new Taylor Fulscope Controller. It's adaptable. It's versatile. Fact is, its unique. The new Taylor Fulscope Controller *grows*, and saves you money by growing.

You may need the Fulscope, at first, to handle simple processing. So you install the basic instrument for that job. Then your needs expand, demanding a controller capable of governing more complicated operations. *Use the same basic Fulscope Controller*—by having other unit assemblies added or substituted in the drilled and tapped Fulscope case. This change-over to a different instrument may be done in the field or on the job. You actually have a new instrument, without having to buy a new one!

Not 1 but 5 available forms of process control—for governing and recording temperature, pressure, liquid level, rate of flow, or combinations—make this Fulscope an essential for *modern* production. It's not a "doctored up" instrument, hasn't merely been "tinkered with" or "improved." This new Fulscope is new. Ask the Taylor man. Or write Taylor Instrument Companies, Rochester, N. Y. Plant also in Toronto, Canada.

Be prepared with Taylor Instruments!

Not 1 but 5 . . . ***All these Forms of Control available in New Taylor Fulscope Controller***

1. Fixed High Sensitivity. **2.** Adjustable Sensitivity. **3.** Adjustable Sensitivity with Automatic Reset (in same case). **4.** Adjustable Sensitivity with Taylor's amazing Pre-Act effect. **5.** Adjustable Sensitivity with Automatic Reset and Pre-Act.

Taylor

Indicating Recording Controlling

TEMPERATURE, PRESSURE, FLOW *and* LEVEL INSTRUMENTS

nozzle. It flushes interior and exterior of the extinguisher, facilitating testing with routine maintenance. Flushing and testing water flows automatically through the pump, without the pump operating. A few strokes are required to bring the extinguisher up to the test pressure.

Paint

THE UNITED STATES STONEWARE COMPANY

A paint developed for protection of metal, concrete and wood surfaces against corrosion and chemical reactions, designated Tygon, has been announced by The United States Stoneware Company, 60 East 42 Street, New York.

It is made to withstand action of nitric, hydrofluoric, hydrochloric, sulphuric and chromic acids, and salts and alkalies. It may be brushed or sprayed, and is available in a wide range of colors. One gallon covers about 200 square feet.

Potentiometer

BROWN INSTRUMENT COMPANY

A circular chart potentiometer to indicate and record temperature has been announced by The Brown Instrument Company, Wayne & Roberts Avenues, Philadelphia.

The instrument's balancing system is continuous, and does not employ a galvanometer. All live parts are enclosed, and sensitivity may be adjusted for correct operation on any standard

Brown Instrument's Potentiometer

pyrometer range to make all amplifiers interchangeable. The balancing motor is a brushless, reversible induction motor with built-in gear reduction. Totally enclosed, it drives pen, pointer and slide rule.

Rectangular case has die-cast door with cam action combination handle and lock provided to draw door tightly against case. A baked black enamel finish is provided to resist corrosion in moist, salt or acid atmospheres. Universal mounting is provided to permit flush or front-of-board mounting.

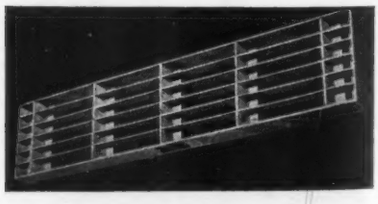
The pointer is 8 inches long, gear driven by balancing motor. Scale is concentric 320°, with 1-inch black boldface numerals on white field graduated the same as the chart to make distant readings visible from any position. Pen and arm are 8 inches long, stainless steel with ribbed reinforcement. Chart is 12 inches wide, and chart clips mounted on the door are provided to hold the chart flat against the chart plate. A synthetic sponge gasket to resist oil is provided to seal the door and make the case dust- and moisture-proof. The pen, pointer and slide wire are directly connected to the balancing motor at all times. A stainless steel cable, unaffected by atmospheric conditions and securely clamped to both slide wire and driving drums, is designed to provide a positive drive to the slide wire.

Grating

ALUMINUM LADDER COMPANY

A grating made of aluminum alloy 61 ST, with a tensile strength rating of 48,000 pounds, has been announced by Aluminum Ladder Company, Tarentum, Pennsylvania.

The grating is designed for use as steps on metal stairs, drains around



Aluminum Ladder Company's Grating

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TROY-ENGBERG STEAM ENGINES

. . . TO WORK { Faithfully / Efficiently / Economically

Oil refinery operations just cannot tolerate anything but the best in these requirements, particularly in the first two. Equipment must do its job dependably and well and at as low a cost as possible.

It's no secret that the reason why Troy-Engberg Steam Engines are so widely used today and are consistently being purchased by refineries is because of these three outstanding characteristics.

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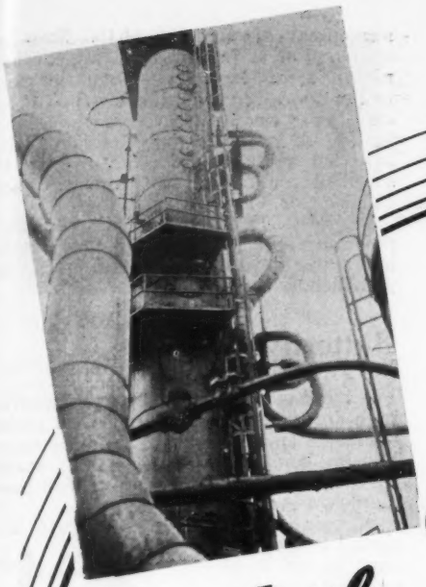

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★

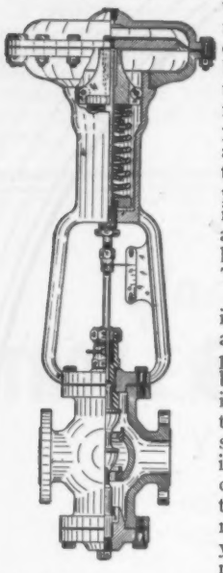
tanks, and for walks on ships carrying volatile cargoes and in plants where fire hazards exist. It is non-sparking, and all-welded construction is designed to insure against bending and buckling.

Weight of the grating is 2 pounds per square foot, and it is available in all lengths and widths.

Motor Valve

HANLON-WATERS, INC.

A motor valve, designated Type 86 and employing frictionless roller guide, with rollers running inside of an enclosed spring barrel on a concentric machined surface designed to provide positive alignment between the diaphragm plate and the stuffing box, has been announced by Hanlon-Waters, Inc., Tulsa.



Yoke of the valve is styled to provide ample room for repacking the stuffing box or for mounting attachments. A travel indicator shows the travel in inches from the closed position on the scale plate mounted on the yoke arm. Body restriction has been minimized to permit inner valve to dominate flow through full travel.

Inner valves are of high-parabolic type, fully reversible in the field without use of special tools or additional parts.

The motor valve is available with iron or steel bodies, and with a number of inner valve and seat materials. Flanging of any series and some bodies with special flange facings are available from stock.

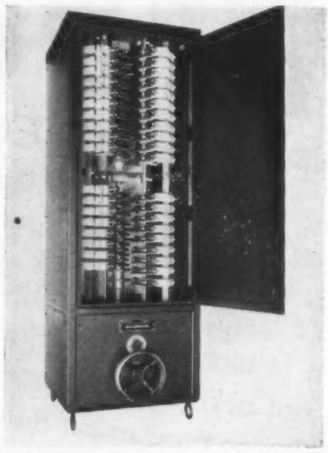
Controller

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

A motor-operated secondary controller for use with polyphase wound-rotor motors on fan, pump and similar drives, has been announced by Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

Designated SC controller, it provides either 13 or 20 balanced points of control by varying external resistance in the motor secondary winding. Enclosed in a self-supporting steel cabinet, the unit has cam-actuated contractors arranged for sequential operation in pairs from a common motor-driven cam shaft. Individual cams are designed to give quick-make and quick-break contact action. Pure silver inlays are provided on contact surfaces to assure excellent current conductivity and avoid heating due to oxidation of the copper base. Separate copper arcing contacts prevent burning or pitting of main contact surfaces.

The controller drive mechanism consists of a pilot motor, a gear reduction unit, and a Geneva gear for angular movement of the cam shaft. Step-by-step action is provided by a gear and pinion arrangement to move the controller one full position or point for each gear revolution. Over-travel protection is provided by auxiliary cam-actuated switches. The motor may be supplied for 115 or 230 volts DC and 110, 220, or 440 volts AC.



Westinghouse Secondary Controller

Optional features, including remote position indication, follow-up attachment and time delay operation, can be provided.

Butterfly Valve

R-S PRODUCTS CORPORATION

A hand-wheel operated butterfly valve with internal parts machined to assist operation and provide a tight fit between housing and vane has been announced by R-S Products Corporation, 4530 Germantown Avenue, Philadelphia.

A pair of adjustable stops are designed to stop the vane in either of two set positions between open and closed, permitting constant duplication of any set maximum or minimum opening in addition to full-open and tight-closed positions. Valves have a graduated dial and pointer for exterior determination of the butterfly vane.

R-S Products' Butterfly Valve

The hand-wheel assembly operates through a self-locking worm and quadrant, and is arranged on the side of the housing so the wheel can be located in the most convenient position. Wheels, worm and quadrant can be omitted and a lever connected directly to the butterfly vane shaft for hand-lever operation.

The line includes a standard range of sizes from 2 to 48 inches, for working pressures up to fifteen pounds.

Ratchet Wrench

J. H. WILLIAMS & CO.

A reversible ratchet wrench 4½ inches long and with a ¼-inch square drive has been added to the Superratchet line of J. H. Williams & Co., 225 Lafayette Street, New York.

It employs a double-tooth pawl for both on and off rotation. A shift lever at the head is provided to reverse the wrench action. The handle is drop-forged from high-tensile carbon steel, and working parts are machined from chrome-molybdenum steel and heat-treated. The wrench is finished in chrome-plate over nickel.

Williams' Reversible Ratchet Wrench

Bearing

LINK-BELT COMPANY

A babbitted-bearing, designated Common Flat Box Series 2-1200 and designed for moderate speed and power requirements, has been announced by Link-Belt Company, 307 North Michigan Avenue, Chicago. It is available

STEEL CONDENSER TUBES

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SIZE	GAUGE	LENGTHS
⅝"	16	10' to 20'
¾"	16	10' to 20'
¾"	14	10' to 20'
1"	12	10' 6" to 24'
1¼"	6	20'
1½"	12	20' to 21' 1½"
1½"	8	16' 2½" to 20'
2"	8	20'
2"	11	20'

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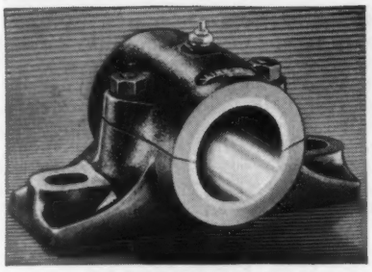


Link-Belt's Series 2-1200 Bearing

from stock in 24 sizes, for shafts of ½ to 3 inches in diameter.

Design features include sloping surfaces between cap and base to maintain concentricity and to relieve the cap bolts of direct strain from side thrust; removable shims between base and cap to provide for needed adjustment; reinforced cap bolt lugs for proper distribution of metal where holding strain is exerted; cap bolts that do not protrude above top of bearing; babbitt of a formula selected in operative tests for maximum service; bore broached to size with cap in place to provide concentricity and proper running fit on shaft with less friction and lower power consumption; bearing ends finished to provide accurate bearing surfaces for collars, pulleys, gears, sprockets or other limiting devices; bearing cap tapped for grease cup or hydraulic fitting with a groove in cap bore to provide efficient distribution of lubricant; base ground to close tolerance; base recessed to compensate for inaccuracies in surface of the structural support; heads of cap bolts easily accessible and anchored to prevent turning, and elongated holes for base holddown bolts to provide adjustment for shaft alignment.

Resistors

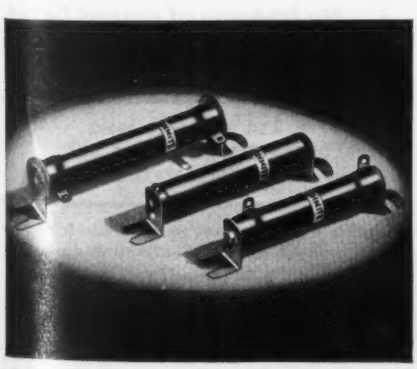
OHMITE MANUFACTURING COMPANY

Wire-wound vitreous-enameled resistors, offered in live-bracket and dead-bracket types for special applications, have been announced by Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago.

The live-bracket type resistors have flexible leads connected to tin-plated brass brackets. They are designed for mounting and making electrical connection by bolting the slotted brackets to panel terminals.

The dead-bracket type is mounted by bolting to the brackets. Electrical connections are made separately to the lugs. The brackets for one, two or three resistors are mounted to the resistors by means of through-bolts. Leakage distance from lug to bracket can be regulated by use of mica washers or by having the lugs located as far in as required.

Both types are available in a range of core sizes with diameters from 9/16-inch to 2½ inches. They are made-to-order according to specifications.



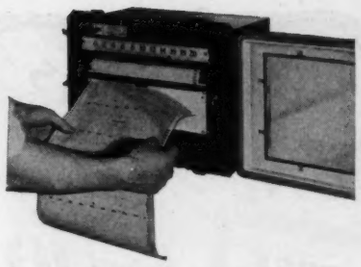
Ohmite Manufacturing's Resistors

Recorder-Controller

C. J. TAGLIABUE MANUFACTURING COMPANY

Recorder-controllers of C. J. Tagliabue Manufacturing Company, Park & Nostrand Avenues, Brooklyn, New York, are now supplied with a tear-off feature consisting of a bar and a reroll with clip and tape. The clip is designed to firmly grip the chart after a section has been removed.

The feature permits filing of short chart strips for ready reference, and makes possible a chart record for a sin-



Tagliabue Recorder-Controller

VINSON SUPPLY COMPANY

Carries in stock **25 CARLOADS**

of National Tube Products to give **IMMEDIATE SERVICE** on YOUR Refinery Requirements

A complete line in ALL Refinery Sizes of National Condenser Tubes as well as Standard, Extra-Heavy and Double Extra-Heavy Seamless Pipe. Large OD Seamless carried in sizes from 14" OD to 24" OD, in several wall thicknesses.

Pierced from solid billets of finest steel —*"The Best that money can buy!"*... National's *"Complete Tube Service"* together with the experience of VINSON SUPPLY COMPANY in anticipating Refinery requirements, assures you not only the widest selection of steel analyses, but also the longest continuous still tube—*up to 52 feet.*

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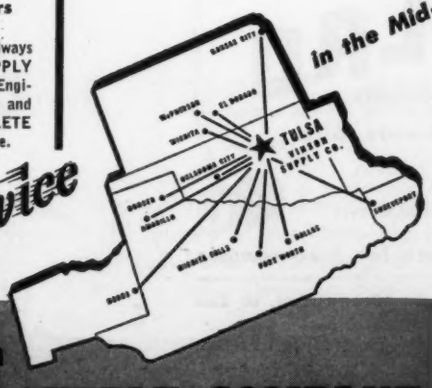
A Fisher Trained Engineer is always available at VINSON SUPPLY COMPANY and Five Fisher Engineers travel out of the Tulsa and Dallas offices giving a COMPLETE Sales and Installation Service.

Fast Service



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Distributors of TUBE-TURNS OUR $35,000 STOCK Insures IMMEDIATE DELIVERY

not 1 out of 2
not 3 out of 4
not 4 out of 5
but
more than 9 out of 10
FREE WORKING SAMPLE

90%+ is mighty close to being unanimous. And that's the percentage of engineers who have become permanent users of PELRO Packing after testing a sample in a stuffing box.

Why does this packing sell itself so completely? The answer lies in its long, strong, high-quality fibres, and its large reserve supply of lubricant, secured by impregnating each individual strand with a special solvent-resisting lubricant under pressure while hot.

Make this* FREE *Test

You, too, are invited to make the test that has convinced so many other engineers. Just send us your name and address on the coupon below, stating the size and service for the packing. A working sample will be sent you, without charge or obligation.

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gle day or a single batch or run. When daily records are required, a special chart can be obtained with hour markings, and with sufficient space to allow for resetting on correct time line.

Stack Blower

THE INFERNO COMPANY

A high-velocity steam stack blower, designed to operate at 200 percent rated capacity on 2 percent of the steam generated by the boiler, has been announced by The Inferno Company, Shreveport.

Streamlined in design to cause minimum resistance in the stacks of the boilers, it is made of malleable iron and is equipped with stainless steel nozzle jets.

Inferno Company's Stack Blower

Hose

THE B. F. GOODRICH COMPANY

Improvements in its high-pressure butane-propane hose have been announced by The B. F. Goodrich Company, Akron, Ohio.

The hose employs two hawser cord braids with a fabric backing over the tube to increase resistance to diffusion. Rated flexibility has been increased from three to five times with rated working pressure remaining at 300 pounds.

Tube Cleaner

AIRETOOL MANUFACTURING COMPANY

A cleaner for catalyst reactor tubes designed to remove hazards from burns and dust during the cleaning operation, has been announced by Airetool Manufacturing Company, Shuey Building, Springfield, Ohio.

The cleaning unit is connected to the bottom header, and a cutter head feeds upward into the catalyst. As the catalyst is loosened, it drops by gravity into the housing and is conveyed into a suitable receptacle placed under the unit. This receptacle and housing are covered to prevent exhausting dust or small particles of spent catalyst into the atmosphere. When the receptacle is filled, it is removed. The entire unit is mounted on a carriage so that it can be rolled into position.

Airetool Catalyst Tube Cleaner

Electric Welder

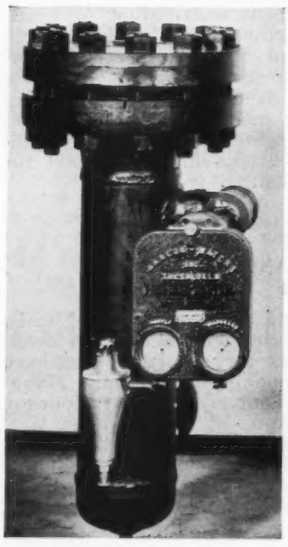
EMERSON ELECTRIC MANUFACTURING COMPANY

A line of four AC arc welders of 75-150-, 200- and 300-ampere capacities has been announced by Emerson Electric Manufacturing Company, St. Louis.

The welders feature an inclined selec-

HANLON-WATERS' ★ Answer for the CONTROL of Liquids OF ANY GRAVITY, TEMPERATURE OR WORKING PRESSURE

★ **Hanlon-Waters Type 850**



THE **ONLY** LEVEL CONTROLLER WITH
NO . . . . . STUFFING BOX
. . . . . LEAKAGE
. . . . . FRICTION

★ **No stuffing box to cause leakage under high pressure.**

★ **No freezing of control liquid, causing binding and sticking of valve.**

• ASK THE MEN WHO OPERATE THEM—THEY ARE OUR BEST SALESMEN!

Complete information and prices available at your nearest HANLON-WATERS Branch.

HANLON-WATERS, INC.
TULSA, OKLAHOMA
New York, Chicago, Pittsburgh, Philadelphia, St. Louis, Denver; Shreveport and Lafayette, La.; Fort Worth, Houston, Corpus Christi, Longview and Odessa, Texas.

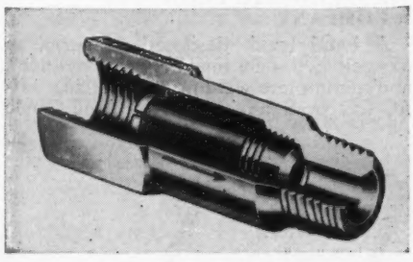
Emerson Electric's Arc Welder

tor panel for clear vision and easy selection of heats from an erect position; heavy-duty on-and-off line switch on selector panel and protected plug and jack connections to eliminate danger of personal injury or damage from accidental contact with connections while in service; drip-proof storage space between selector panel and cabinet front for accessories; panel cover for protection against accumulation of dirt and accidental damage; ventilating louvers on top and sides, and transformer coils wound with copper magnet wire with flexible double-spun glass insulation to withstand temperatures in excess of 1000° F. and to resist moisture, grease and acid.

Strainer

SPRAYING SYSTEMS COMPANY

A strainer designed for use in connection with spray nozzles when foreign matter interferes with efficient operation, has been announced by Spraying



Spraying Systems Company's Strainer

Systems Company, 4021-A West Lake Street, Chicago.

The unit is equipped with ¼-inch pipe connection for inlet and outlet. Standard stock construction is brass with Monel-metal screen. Other materials and sizes can be obtained on specification.

Insoles

E. D. BULLARD COMPANY

Protective insoles for use inside rubber boots and shoes have been announced by E. D. Bullard Company, 275 Eighth Street, San Francisco.

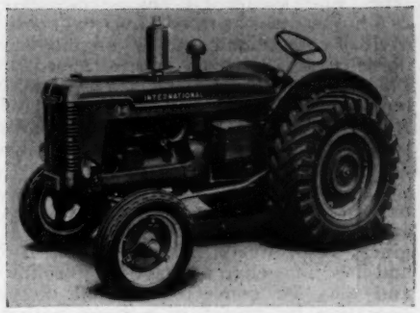
They are comprised of two thin protective layers of a special plastic material to provide puncture-resistance and flexibility, and are provided with a woven glove-fitting cover. Non-absorbent, they weigh two ounces and are available in sizes six to 11. They are designed to be washed frequently without damage.

Tractors

INTERNATIONAL HARVESTER COMPANY

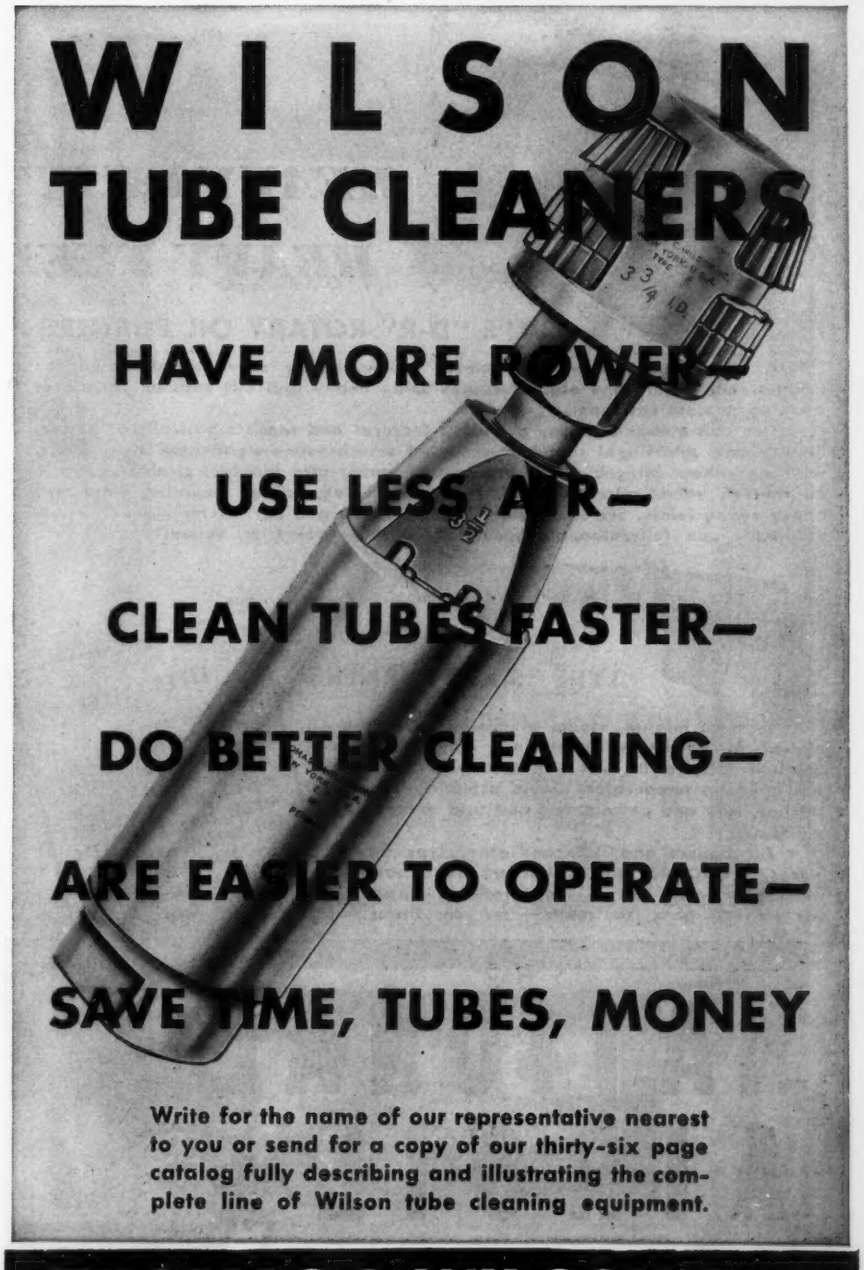
A line of five-wheel tractors, designated the "I" line and including three models with carburetor-type engines and two with diesel engines, has been announced by International Harvester Company, 180 North Michigan Avenue, Chicago.

The new tractors feature Tocco-hardened crankshaft, pressure lubrication, replaceable cylinders, five forward speeds, gear drive, countershaft brakes that may be individually controlled or interlocked and provision for mounting a variety of allied equipment. Three of the models have forward speeds up to 15 miles an hour, and two up to 14 miles an hour.



International's Model I-4 Tractor

Models of the carburetor-type engines are designated as I-4, I-6 and I-9, and engines are 4-cylinder valve-in-head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TUBE CLEANERS
HAVE MORE POWER—
USE LESS AIR—
CLEAN TUBES FASTER—
DO BETTER CLEANING—
ARE EASIER TO OPERATE—
SAVE TIME, TUBES, MONEY
Write for the name of our representative nearest to you or send for a copy of our thirty-six page catalog fully describing and illustrating the complete line of Wilson tube cleaning equipment.
THOMAS C. WILSON, Inc.
PIPE AND TUBE CLEANERS EXCLUSIVELY
47-28 37th Street
Long Island City, N. Y.

type. The Model I-4 engine develops 29.5 horsepower at rated governed speed of 1650 revolutions; the I-6 engine 40.5 horsepower at rated governed speed of 1450 revolutions, and the I-9 engine 54 horsepower at rated governed speed of 1500 revolutions. Bore and stroke are, respectively. 3⅜ by 4¼ inches; 3⅞ by 5¼ inches, and 4.4 by 5.5 inches.

The diesel-powered tractors, designated ID-6 and ID-9, are, in dimensions and other characteristics excepting engines, respectively similar to the I-6 and I-9. The engines start on gasoline, and may be converted to full diesel operation by means of a lever within reach of the driver.

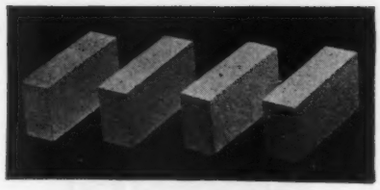
The engine of the ID-6 develops 38.5 horsepower at rated governed speed of 1450 revolutions, and that of the ID-9 develops 51.5 horsepower at rated governed speed of 1500 revolutions. The bore and stroke of the ID-6 are 3⅞ by 5¼, and of the ID-9, 4.4 by 5.5 inches.

Fire Brick

JOHNS-MANVILLE

A line of insulating fire brick for temperature range from 1600° to 2600° F. has been announced by Johns-Manville, designed for direct exposure in furnaces, ovens and other heated equipment except where subject to slag action or mechanical abuse.

The brick are furnished in four temperature limits: JM-16 for exposed service to 1600° F. and for back-up service to 2000° F.; and JM-20, JM-23, and JM-26 for exposed or back-up temperatures to 2000°, 2300° and 2600° F., respectively. The new line supplements



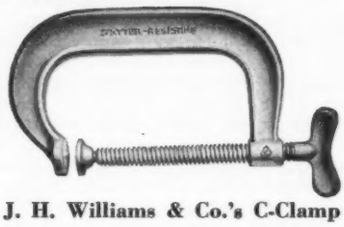
Johns-Manville Fire Brick

the Johns-Manville Sil-O-Cel series of back-up insulating brick for temperatures of 1600°, 2000° and 2500° F.

The brick are produced from a plastic refractory clay and an organic filler which, upon being burnt out during the manufacturing process, is designed to give a uniform, controlled pore structure to each of the various types and to impart characteristics of light weight, strength and high insulating value.

Clamp

J. H. WILLIAMS & CO



J. H. Williams & Co.'s C-Clamp

A C-clamp featuring a cadmium finish to resist adherence of welding spatter to the body, swivel and screw has been announced by J. H. Williams & Co., 225 Lafayette Street, New York.

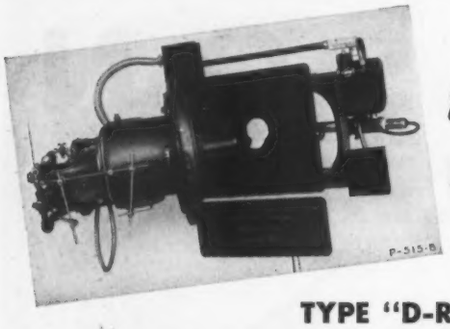
The clamp is offered is seven sizes, with capacity opening range from 2 to 12 inches.

Cylinder Truck

THE LINDE AIR PRODUCTS COMPANY

A hand truck designed to carry an oxygen cylinder, an acetylene cylinder, and a complete welding and cutting outfit, has been announced by The Linde

Linde Oxweld T-7 Welding Truck



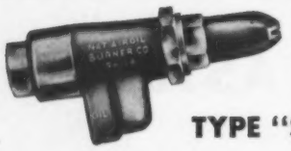
for

HEAVY DUTY, HEAVY FUEL

TYPE "D-R" ROTARY OIL BURNERS

A complete, self-contained, motor driven, heavy duty unit designed for firing steam boilers and other furnaces using heavy fuel oils such as petroleum cracking process residuums.

This unit embodies many exclusive features and consists basically of motor, blower and centrifugal atomizer mounted on chrome-molybdenum steel shaft, with or without integral worm-driven fuel pump; also has fuel strainer, electric oil shut-off valve, micrometer oil regulating valve, burner mounting plate and heavy swing joints. Six sizes; capacities up to 90 gal. per hr. for manual, semi-automatic and full-automatic operation. Details—yours on request.



TYPE "S.A." BURNERS

Internal mixing, steam atomizing burners designed to handle efficiently not only the usual grades of industrial oils but residual fuels, high and medium temperature liquid asphalts, viscous pitches, tars and petrolatums and acid or caustic sludges.

For boilers and stills and other type furnaces, NATIONAL AIROIL burners soon save their own small cost . . . and refiners agree: no others give so much — for so little!

LITERATURE

describing the complete line of National Airoil Burner equipment for oil refinery service — free on request. Write NATIONAL AIROIL BURNER CO., 1254 East Sedgley Ave., Phila., Pa.—"Specialists in Burning Oil More Economically for Over a Quarter Century."

NATIONAL AIROIL BURNER

NATIONAL AIROIL BURNER

Air Products Company, 30 East 42 Street, New York.

Designated Oxweld T-7 two-wheel welding truck, it has 14-inch wheels equipped with semi-pneumatic rubber tires. The truck presents a 4½-inch reduction in overall width from former models, and the size of the removable metal tool box for extra blowpipes, tips, goggles and wrenches has been increased.

Starters

GENERAL ELECTRIC COMPANY

Two wall-mounted low-voltage oil-immersed starters designed to resist corrosive fumes have been announced by General Electric Company, Schenectady, New York. Designated CR7008 and CR7006, the starters feature a heavy, corrosion-resisting, cast-iron head supporting the mechanism and oil tank. Stainless steel nameplates and corrosion-resisting hardware further protect them against damage. Working parts are enclosed in a 3/32-inch steel tank. Special provision is made in the head for simplified installation. Conduit entrance is provided for on the top, bottom, rear and sides of the starter, eliminating necessity for right-angle fittings.

Type CR7008 is a combination starter, combining in a single unit equipment for controlling and protecting a motor. It includes a manually operated circuit breaker for short-circuit protection and disconnecting, and a magnetic starter for push-button control of the motor. Enclosing tank cannot be lowered while the circuit breaker is on. Operating handle for the circuit breaker can be padlocked in either the on or off position to prevent operation by unauthorized persons. Manual circuit breaker, designed for operation under oil, has a rating of 10,000 amperes interrupting capacity to protect the motors, starters and personnel from injuries caused by short circuits.

Type CR7006 is a magnetic starter similar to CR7008, except that it does not include manual circuit breaker and its operating handle in the cover. It is recommended for use where other provision has been made for short-circuit protection and disconnecting.

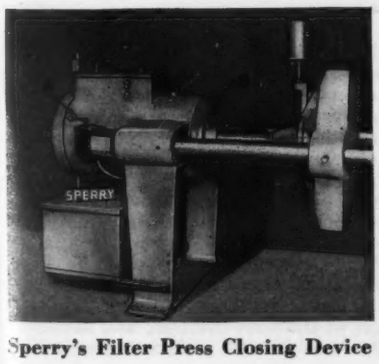
Both starters are available in types for use in hazardous-gas locations.

Filter Closing Device

D. R. SPERRY & COMPANY

An electrically operated hydraulic closing device for filter presses, designated Type EHC, has been announced by D. R. Sperry & Company, Batavia, Illinois. It can be applied to existing filter press installations without inordinate expense or making extensive alterations in the equipment.

The press is controlled by adjustments at two places. To open, controller handle (A) is moved forward, locknut (B) is loosened by unspinning about two turns, filler block is then swung upward, and the movable head is pulled back into open position. To close press, head is pulled forward to contact plates and frame, filler block is then dropped into place, controller handle is moved forward, press is squeezed to desired pressure as shown on the indicating gauge and locknut is spun into tight position.



Sperry's Filter Press Closing Device

Gloves

RESISTOFLEX CORPORATION

A line of transparent gloves designed to prevent oils and solvents from coming into contact with the skin has been announced by Resistoflex Corporation, Bellevile, New Jersey.

Made of Resistoflex PVA, a substance described as offering high resistance to tearing and abrasion, they are designed to resist organic solvents or active solvents, such as benzol, carbon disulphide and chlorinated hydrocarbons. When soiled, they may be cleaned in lacquer thinner, turpentine, carbon tetrachloride or gasoline. While not as flexible as rubber or synthetic rubber gloves, they are described as sufficiently flexible to afford unrestricted movement of the fingers and not to cause undue awkwardness or discomfort.

The gloves are available in sizes 8, 9, 10 and 11, the three smaller sizes being produced in 10½- and 14-inch lengths, while size 11 is made in 10½-, 14- and 18-inch lengths.

Specially Developed For Severe Oil Service

GARLOCK 7021 Compressed Asbestos Sheet Packing gives superior performance against light oils at high temperatures and against super-heated steam at extreme pressures. It is recommended for pipe lines, cracking stills and other equipment handling gasoline, light oils, gas and steam. Specify GARLOCK 7021!

THE GARLOCK PACKING COMPANY
Palmyra, New York

Tulsa, Oklahoma
Houston, Texas
Los Angeles, California

Garlock 7021
COMPRESSED ASBESTOS SHEET PACKING

BUSINESS NOTES

Houston Offices of Petroleum Rectifying and Tretolite Moved

Gulf Coast division headquarters of Petroleum Rectifying Company of California and Tretolite Company have been moved from the Petroleum Building to 5121 South Wayside, Houston. The new building houses offices, laboratory and warehouse facilities of the two companies.

Du Pont to Build Neoprene Plant at Louisville, Kentucky

E. I. du Pont de Nemours & Company, through President W. S. Carpenter, Jr., last month announced construction of a new neoprene synthetic rubber plant at Louisville, Kentucky.

Construction will start immediately, and the plant will have a capacity of 10,000 long tons a year, exceeding the present 6000-long-ton total combined production of synthetic rubbers made at the company's plant at Deepwater, New Jersey. Additional facilities now under construction will increase production at the Deepwater plant to 9000 long tons a year.

The new construction is intended to provide a supply of neoprene that will be adequate for all defense and commercial needs. Neoprene now is on the government's mandatory priority list.

Builders-Providence, Inc. Is Meter Subsidiary of Builders Foundry

Builders Iron Foundry, Providence, Rhode Island, has announced it will conduct its metering business under the name of Builders-Providence, Inc., and as a division of Builders Iron Foundry with the same directors and officers.

The company was started in 1820 as a foundry mainly to supply cast iron columns and miscellaneous cast iron hardware then being used in construction of buildings. A machine shop was added several years before the Civil War, and since then the company has been engaged primarily in manufacturing.

Canadian Lincoln Electric Completes New Building

Canadian Lincoln Electric Company has completed a new plant at Leaside, Ontario. The unit was constructed by fabrication of structural steel at the job site, eliminating delays induced by priority war orders.

The building has exterior dimensions of 302 x 100 feet, with general offices in a space 40 feet wide extending the full width of the building across the front. There are eight bays of monitor-type roof with end bays of flat-roof construction. As many windows as possible were set in all walls, and continuous glazed sash on inclined portions of the raised roof.

York Export Force Moves To Pennsylvania

The Export Division of York Ice Machinery Corporation has completed transfer of its personnel from the Brooklyn office of the corporation to the main factory offices at York, Pennsylvania.

J. C. Tweedell, manager of the Export Division, said the move will enable the company to provide direct factory assistance for our foreign representatives. To continue close cooperation with export firms in the metropolitan area, the company will retain export sales representatives in New York City.

Buda Engine & Equipment Moves Headquarters to Dallas

Buda Engine & Equipment Company has moved its head office and central warehouse from Houston to 1901 Canton Street, Dallas. The company will continue to maintain an office and store in Houston.

It's not packing—it's **RE-*packing that's really expensive*...** That's why it pays in dollars and cents to use the best packing money can buy. J-M Sea Rings are that kind of packing.

They're custom-made to fit specific operating conditions. Entirely automatic, they seal on the work stroke, release on the return, thus reducing friction and wear on both packing and rod. During the past 25 years many engineers have accepted Sea Rings as the standard packing for reciprocating rods and plungers operating against steam, water, air, brine, oil, gasoline and many other fluids and chemicals.

For details on J-M Sea Rings and the complete line of J-M Packings and Gaskets, write Johns-Manville, 22 East 40th Street, New York, N. Y.

JM

Johns-Manville PACKINGS & GASKETS

THERE'S A DISTRIBUTOR NEAR YOU

Supply Personals

M. J. Warnock has been named director of advertising and promotion for Armstrong Cork Company, Lancaster, Pennsylvania, under a new expanded advertising department that new covers all promotional activity. He succeeds John P. Young, resigned, and is to be aided by E. Cameron Hawley as assistant director of advertising and promotion. Warnock joined the company in 1926, spending 3½ years in the Seattle district as salesman and later as district manager. He later was assistant manager of the floor division, and earlier this year was named assistant general sales

manager. Hawley joined the company in 1927 as a member of the advertising department. He was later assistant sales manager of the Corkwood division, director of commercial research, and since 1936 has been director of the bureau of retail merchandising for the floor division.

James Coombe has been elected president of Wm. Powell Company, Cincinnati. With the exception of 2½ years he served over-seas as artillery captain in the first World War, he has been associated with the company since his graduation from Yale University in 1910. Other officers elected are Harry H. Coombe, board chairman and treasurer; George E. Weitkamp, first vice president and secretary; David M. Forker, Oliver F. Gang, William E. Heilig and E. R. Noll, vice presidents, and William E. Minor, Jr., assistant to the president.

James Coombe

Edwin H. Price, Los Angeles representative for Manning, Maxwell & Moore, Inc., and a lieutenant commander in the United States Naval Reserves, has been called to active duty. He is serving as assistant supervisor of shipbuilding at the Union Iron Works plant of Bethlehem Shipbuilding Corporation at San Francisco.

V. P. Rumely, works manager at the Chicago plant of Crane Company, has been named vice president in charge of manufacturing, succeeding J. H. Collier, who recently was made president of the company. Rumely studied mechanical engineering at Purdue University and later at the University of Wisconsin, graduating in 1912. His first job was in the farm implement plant of his grandfather, M. Rumely, in La Porte, Indiana. In 1914-15, he was with Buick Motor Company, and in 1916 went to Hudson Motor Company. Starting in the Hudson Motor Company shops, he progressed through every stage of production management to superintendent and factory manager, the position he held when he resigned to join Crane Company in 1937.

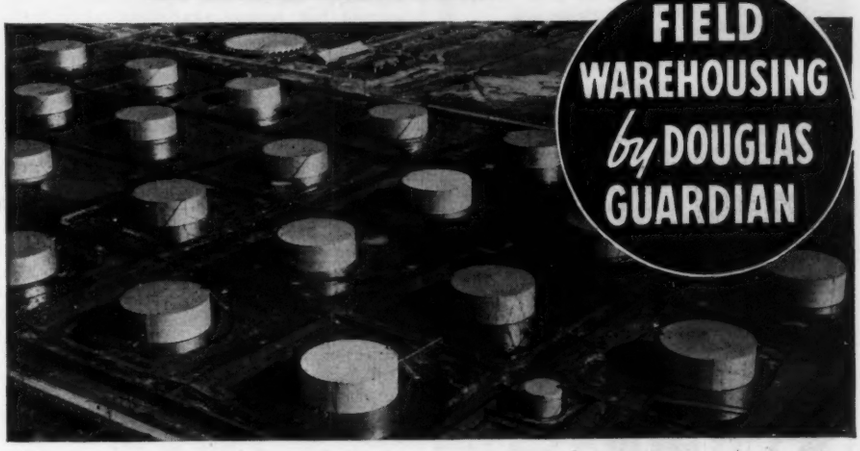
V. P. Rumely

W. G. Skelly was re-elected president of the International Petroleum Exposition at the annual meeting of the board of directors held in Tulsa last week, and plans were formulated for the twelfth show to be held May 16-23, 1942. Skelly has served as president since 1926. Other officers re-elected were Franks J. Hinderliter and Alf G. Haggen, vice presidents; Clyde H. Pape, treasurer, and Frank O. Prior and M. W. Bovaird, executive committee members. William B. Way, general manager, announced that 59.8 percent of the space for the 1942 show has been reserved, which is the first time in the history of the show that such a large amount has been taken a year in advance. Officers and directors stressed the fact that the show will be more important than ever during the time of stress the nation is now undergoing, since it serves to acquaint the industry with the latest methods and equipment—a necessary factor in a period when cheaper, quicker, and better ways of producing oil are sorely needed.

John H. Collier, vice president in charge of manufacturing for Crane Company, Chicago, has been named president, suceeding the late Charles B. Nolte. He joined the company in 1903 on leaving school, starting as core-maker's helper. He was named general manager of the Bridgeport plant in 1917; was made president of Cie Crane, Paris, and chairman of Crane, Ltd., London, in 1929, and became vice president in charge of manufacturing in 1933.

Fred W. Bush and W. C. Sealey have been named engineer in charge of transformer sales and engineer in charge of transformer design, respectively, for the Allis-Chalmers Manufacturing Company, Milwaukee. Bush, a graduate of Georgia Tech, joined the company in 1928, and has been connected with transformer engineering, development and sales since 1930. Sealey, a graduate of Carnegie Tech, joined the company's transformer division in 1931, when the company absorbed the American Brown Boveri interests, and prior to 1928 was

WHEN YOU NEED MONEY—
Put Inventory TO WORK WITH



PETROLEUM PRODUCTS in tanks, tank cars, barrels or other suitable storage, are easily converted into the money you need, under Field Warehousing by Douglas-Guardian. We bring the warehouse to your inventory. Create collateral of a high degree, for a bank loan, obtained promptly and on favorable terms.

We've had 18 years' experience. Render a smooth-working, complete service, devoid of detail or red tape for bank or borrower. Financially sound. Highest references. **Mail coupon for Booklet or a "call."**

INVESTIGATE this modern aid to financing. WRITE for our FREE Booklet. One of our experienced field men will be glad to call. **Use the convenient coupon.**

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Los Angeles, Cal.	Springfield, Mass.	
Memphis, Tenn.	Tampa, Fla.	
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DOUGLAS-GUARDIAN WAREHOUSE CORP.
Tower Petroleum Bldg., Dallas, Texas

☐ O. K. to have your representative call. (No obligation.)

☐ Send your booklet "Financing the Modern Way."

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For attention of_____

These 3 Cements will enable you to do hundreds of repair and maintenance jobs quickly and at low cost

Here are some of the many emergency repair and routine maintenance jobs you can do quicker and at less cost with these three Smooth-On compositions than by any other means:

Seal cracks in casings or shells of pumps, heaters, condensers, evaporators, tanks, engines, valves, etc.

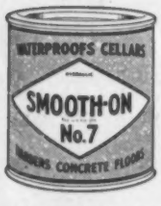
Stop leaks at seams, bolts, rivets, threaded or flanged joints, etc.

Tighten loose parts of apparatus, fixtures, etc.

Waterproof walls, floors, cisterns, etc., of concrete, brick or stone.

Seal Joints of threaded or flanged pipe and equipment connections.

Anchor studs, bolts or screws in concrete, metal or wood.



Re-surface damaged piston heads, valves, machine castings, etc.

Correct for misalignment of joints at connections of piping, equipment, machine bases, etc.

Reinforce thin or punctured metal weakened by force, corrosion or abrasion.

This partial list of Smooth-On time-saving and labor-saving uses shows how *essential* these compositions are for every plant.

These Smooth-On compositions are sold in 1-lb., 5-lb. cans; larger kegs. Smooth-On No. 1 is also sold in 1¾-oz., 7-oz. cans. For your protection, insist on Smooth-On, used since 1895. Obtainable from your supply house or if necessary, from us.

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40-PAGE HANDBOOK

Explains simply and concisely how to do each of the above and many other repair and maintenance jobs, with 170 illustrative diagrams. Send the coupon TODAY for your copy of this helpful manual which every engineer should have and keep handy.

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Do it with
SMOOTH-ON

connected for several years with the transformer division of Westinghouse Electric & Manufacturing Company.

A. F. Dohn, vice president in charge of tool steel sales of Allegheny Ludlum Steel Corporation, has announced his retirement. He will continue in a consulting capacity as a vice president of the company. He was with Buffalo Engine Company as sales manager and secretary - treasurer, and opened his own sales office in Buffalo in 1912. Three years later, he joined Atlas Steel Company, becoming vice president in charge of sales in 1916, and president in 1924, continuing in that capacity until 1929 when his company merged with the former Ludlum Steel Company. He was vice president in charge of sales until the Allegheny Ludlum merger in 1938, when he assumed his recent status as vice president in charge of tool steel sales for the enlarged corporation, with headquarters at the Watervliet, New York, plant.

A. F. Dohn

Oscar N. Lindahl, comptroller and secretary of the Universal Atlas Cement Company has been elected vice president in charge of finance for Carnegie-Illinois Steel Corporation, Pittsburgh. He succeeds M. D. Howell, who will devote all his time to duties as vice president, secretary and treasurer of United States Steel Corporation of Delaware. Born in Sweden, Lindahl came to America, and attended public and private schools in Chicago. He was employed by Butler Brothers in Chicago from 1900 to 1907, when he joined Illinois Steel Company. He joined Universal Atlas Cement Company in 1911, serving successively as general bookkeeper, chief accountant, auditor and assistant secretary, and comptroller and secretary.

D. A. Kalton and A. W. Thomas have been named assistants to the sales manager of the construction equipment division of Chain Belt Company, Milwaukee. Kalton joined the company in 1932 on graduation from Marquette University, and has served in the home office sales department and as eastern district manager. Thomas, a civil engineering graduate of Purdue University, joined the company in 1927. He has been connected with both sales and engineering departments of the construction equipment division.

Dr. C. F. Rassweiler has been named director of research for Johns-Manville Corporation, New York. He has been director of the Philadelphia laboratory of E. I. du Pont de Nemours Company. Born in Polo, Illinois, Dr. Rassweiler was graduated with a bachelor of science degree in chemistry from the University of Denver in 1920. He secured his master's degree from the University of Illinois in 1922, and his Ph.D. from the same institution in 1924. He joined the du Pont organization in 1924 as a research chemist, and since 1932 he has been director of the du Pont Laboratory in Philadelphia.

J. H. Gillette, specification and instrumentation engineer for Arthur G. McKee & Company, died suddenly May 21. He maintained his home at Cleveland.

Earl Snyder, water technologist for D. W. Haering & Company, Chicago, has been named Houston district manager with headquarters at 726 Electric Building. C. E. Erb, water technologist, has been named Wichita division manager, with office and laboratory at 557 West Douglas.

W. R. Swoish has been named vice president in charge of sales, and James E. Vevan, vice president in charge of manufacturing for Roller-Smith Company, Bethlehem, Pennsylvania. Swoish

POSITION WANTED: Experienced as asst. stillman, process helper, boilerman. Just returned from foreign service. Experience in Alkylation and Polymerization. Would like association where experience crude still operation may be obtained. Willing to go anywhere in U. S. References: Standard Oil of New Jersey. Replies, L. M. Kenny, 1821 Topping Ave., Bronx, New York City.

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EVALUATION
AND
GAS ANALYSIS WORK
WITH LABORATORY FACILITIES IN HOUSTON

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graduated from Ohio State University in 1921 and then joined Westinghouse Electric & Manufacturing Company, where he was a member of the switchgear sales department, salesman in the Buffalo territory, sales manager of the distribution transformer section, sales manager of the oil circuit breaker section and switchgear sales maanger. He joined Roller-Smith in January, 1939, as sales manager. Bevan graduated from Lehigh University in 1925, entered the employ of Roller-Smith in 1928 after previously having been connected with Bethlehem Steel Company and Philadelphia Electric Company. From 1928 to 1930, he engaged in plant efficiency work. The following three years were spent as a salesman in the New York office. In 1933, he returned to Bethlehem as a switchgear specialist, and was appointed assistant chief engineer in 1939. In 1940, Bevan was placed in charge of the Allentown plant of Roller-Smith.

Fred W. Muller has been named manager of Armstrong Cork Company's high temperature insulation department, succeeding Fred M. Ritts, who has been made assistant manager of the newly organized munitions division of the company. Muller was graduated from Alfred University, Alfred, New York, in 1933. He has been with the Armstrong organization since 1937, and was connected with the company's Detroit office.

William A. Marsteller has been appointed advertising and sales promotion manager for The Edward Valve & Manufacturing Company, East Chicago, Indiana.

Ralph H. Layte, executive vice president of Purolator Products, Inc., Newark, New Jersey, has been elected president of the company. Joining the company in 1925, he was made assistant to the president in 1927, and elected first vice president in 1938. John A. Graham, who Layte succeeds as president, has been named honorary board chairman.

Norman L. Deuble, assistant to the vice president of Copperweld Steel Company, Warren, Ohio, has been appointed manager of sales. A graduate of Case School of Applied Science, he was with Republic Steel Corporation, Central Alloy Company, and United Alloy Steel Company before joining Copperweld.

Robert Rast Cole, general manager of the phosphate division of Monsanto Chemical Company, has been elected a vice president of the company. Following graduation from Technical High School in Columbus, Georgia, he taught mechanical engineering in the school for a year, and then took a course in mechanical engineering at Cornell University. From 1912 to 1914, he was apprentice foreman in the Central of Georgia railroad shops at Macon, Georgia. From 1914 to 1916, he

R. R. Cole

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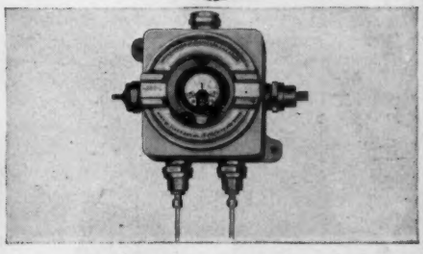

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was assistant superintendent of the Southern Car Wheel Company at Savannah, leaving to go with the Anniston Ordnance Company as engineer. Later, he was chief engineer of the Southern Manganese Corporation, and in 1920 he became general superintendent of the Southern Manganese Corporation, later the Swann Corporation. When Swann was absorbed by Monsanto in May, 1935, Cole became assistant to the late R. J. Hawn, vice president. In November, 1938, he was made production manager of the phosphate division, and in May, 1939, general manager in charge of the division's research and sales activities as well as its manufacturing operations.

Stephen B. Haynes has been elected assistant treasurer of Cochrane Corporation, Philadelphia. A 1924 graduate of Yale University, he had previously been associated with the Mathieson Alkali Works, Inc., in a sales promotional capacity, and Associated Drygoods Corporation, in financial work.

Charles B. Jahnke, president and general manager of The Cooper-Bessemer Corporation, died in Mount Vernon, Ohio, May 6, following a heart attack. Born at Cincinnati in 1889, he graduated from the University of Cincinnati and was for 21 years associated with Fairbanks, Morse & Company, having achieved the positions of chief engineer, works manager and finally director of engineering. In 1931, he joined International Harvester Company. Four years later he became affiliated with The Cooper-Bessemer Corporation as its chief engineer. In 1937, he became a vice president and general manager of the corporation and, on December 27, 1940, was elected to the office of president.

M. R. Dill has been named a director and general counsel of The Lincoln Electric Company, Cleveland. He attended the Wharton school of the University of Pennsylvania for his pre-law education, and in 1930 graduated from the law school of Ohio State University. On graduation, he joined the Cleveland law firm of Squire, Sanders & Dempsey.

M. R. Dill

Re-elected were: J. C. Lincoln, board chairman; J. F. Lincoln, president and general manager; C. M. Taylor, vice president; A. F. Davis, vice president and secretary; G. G. Landis, chief engineer; Harold F. Kneen, plant superintendent, and J. W. Meriam and W. B. Stewart, directors.

Lee H. Hill, former assistant manager of the electrical department of Allis-Chalmers Manufacturing Company, Milwaukee, has been named a vice president and head of a newly created industrial relations department. He will be in charge of collective bargaining, grievance procedure, employment, wage policies and levels and all other subjects bearing on management-employe relations. W. C. Van Cleaf continues to work in industrial relations, reporting to Hill.

Lee H. Hill

L. J. Lynch has been named Detroit district representative for Morris Machine Works, Baldwinsville, New York. He will make his headquarters at 403 Kales Building.

Ralph M. Hoffman, assistant to the president of Link-Belt Company since January, 1940, has been made a vice president with general direction and supervision of sales. A 1911 mechanical engineering graduate of the University of Minnesota, he joined the company in 1923 as manager of Link-Belt Meese & Gottfried Company's Seattle branch. He served in that capacity until 1931, the name of the subsidiary meanwhile becoming Link-Belt Company Pacific Division, and from 1931 to 1939 served as vice president and sales manager of the subsidiary.

R. M. Hoffman

Jesse J. Ricks, president of Union Carbide and Carbon Corporation, has been named board chairman, and is succeeded as president by James A. Rafferty, former vice president. Robert W. White, secretary-treasurer, has been named a vice president.

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